IMPACT OF LAND USE CHANGE AND CLIMATE VARIABILITY ON STREAMFLOW FOR THE BUDHABALANGA RIVER BASIN (ODISHA)

A DISSERTATION

Submitted in the partial fulfillment of the
requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

Water Resources Development

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in this thesis report entitled "**IMPACT OF LAND USE CHANGE AND CLIMATE VARIABILITY ON STREAMFLOW FOR THEBUDHABALANGA RIVER BASIN (ODISHA)**" in partial fulfillment of the requirement for the award of the degree of **Master of Technology** with specialization in Water Resource Development, submitted to the department of Water Resources Development and Management, Indian Institute of Technology Roorkee, India, is an authentic record of my work carried out under the supervision and guidance of **Dr. Deepak Khare** and **Dr. Prabhash Kumar Mishra**. The matter embodied in this dissertation report has not been submitted by me for the award of any other degree or diploma.

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Place: Roorkee

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CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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ABBREVIATION

CWR	Crop Water Requirement
DEM	Digital Elevation Model
ETc	Crop Evapotranspiration
ET_0	Reference Evapotranspiration
FAO	Food and Agriculture Organization of the United Nation
FIR	Field Irrigations Requirement
GCM	Global Circulation Model
GIS	Geographical Information System
GW	Ground Water
HRU	Hydrological Response Unit
IMD	India Meteorological Department
LULC	Land Use Land Cover
NIR	Net Irrigation Requirement
NBSSLUP	Nation Bureau of Soil Survey and Land Use Practices
NSE	Nash Sutcliffe Efficiency
PBIAS	Percentage Bias
RH	Relative Humidity
RMSE	Root Mean Square Error
SWAT	Soil and Water Assessment Tool
SWAT-CUP	Soil and Water Assessment Tool - Calibration and Uncertainty Procedures
Tmax	Temperature Maximum
Tmin	Temperature Minimum
USDA	United States Department of Agriculture
USGS	United States Geological Survey

ABSTRACT

In recent years for rapid measurement and estimation of spatial information for water resources project, remote sensing and geographical information system has played a vital role in planning and investigating hydrological and meteorological observation of upcoming new and old projects. The dynamic and unpredictable nature of land use and land cover changes in recent decades has become the major intervention for planning, management and sustainable development in Water Resources. The land use and land cover classes like water bodies, barren land and forest land determines the quantity and quality of surface's ground water flow. Due to advancement of recent space research there is ample opportunity to collect spatial and temporal data with adequate accuracy in a very low time with very low cost without going into detailed survey and investigation in inaccessible regions. Hydrology of the Budhabalanga river basin in Northern Odisha is a complex process involving varied topography and climatological changes involving in ecosystem. Land use and land cover (LULC) data is vital for water management analysis of any basin. LULC influences the rate of infiltration, runoff and subsequently the volume of surface and subsurface flow and the total sediment load transported in a basin. In the present study also satellite based LULC classification is made to determine the land surface processes for the Budhabalanga basin.

Apart from this, SWAT, a GIS based semi-distributed hydrological model, is applied for assessing the impact of LULC changes on daily and monthly stream flow in Budhabalanga river basin. SWAT is a robust inter disciplinary comprehensive, semi-distributed model used for estimation of stream flow in watersheds. It requires large number of input parameters that complicates model parameterization and calibration. There are two calibration techniques like manual and automated procedures using a supplied complex evolution methods. In SWAT-CUP the user manually adjust parameters. The statistical goodness of fit is applicable focussing on the calibration and uncertainty analysis. It is important for future calibration developments to spatially amount for hydrological SWAT model process. For advance planning of agricultural or water resources management, the future runoff is predicted. The simulated runoff is calibrated and validated against the observed discharge of Govindpur NHI road bridge provided by the Central Water Commission. The model performance is evaluated with qualitative statistics method like R^2 (Co-efficient of determination), NSE (Nash Sutcliffe

efficiency), Root mean square error (RMSE), PBIAS (Percentage Bias) and RMSE-observations standard deviation ratio (RSR) values indicating good agreement. The study is moreover helpful in designing agricultural production optimization by using sustainable water resources management for future upcoming projects like Kamata irrigation project and Budhabalanga barrage project in the sub-basin.

Also the spatial variability and temporal trends of rainfall has been investigated for seven observatory stations for 30 years period from 1988 to 2018. This is essential because the climate change especially for the factors like rainfall and temperature parameters has impacted significantly in the last decades. Trend detection was carried out using non-parametric tests such as Mann-Kendall (M.K.) test and Sen’s slope estimator to analyze the rate of change in long term series which will be helpful for the two upcoming new projects like Kamata Barrage Project and Banktira irrigation project in the catchment for detailed planning and designing of water resources along with field application for agricultural cropping pattern and development.

CHAPTER 1:INTRODUCTION

1.1 General

Water is an extremely important natural resource used in all fields amongst them the agriculture sector utilises maximum amount of water for crop production. About 95% of irrigation water is met from surface sources worldwide (FAO 1996). The regulation of water supply and flood control are being achieved by construction of dams and barrages across the flow of river and methods in timely creating resources for subsequent uses.

The food production in agricultural sector depends on optimum utilization and availability of water during their growth period & further nourishment. The morphology, land use and soil parameters which are the physical characteristics of a watershed influences the water balance by affecting components in a watershed. The water continues to change its phase in the water cycle. This results in redistribution of water in land and atmosphere which ultimately affects the regional climate (Chow et al., 1988; Subramanya, 2007). The sustainability in agriculture development at the basin level is achieved by spatial temporal mapping of irrigated area, non-irrigated area and water bodies in project area (Gamma et al., 2015). Artificial supply of water to agriculture by utilising rainwater efficiently with construction of storage tanks, bunds etc. started 10,000 years ago, thereby enabling sufficient water for cultivation. This reduced the dependability of agriculture society on rainfall. Total cultivated land worldwide is about 18% which expands to 270 million/hectare (Fischer et al., 2007).

Heterogeneous hydrologic characteristic within watershed system with respect to time and space, making the water resources management very challenging and complicated. Scientific method and approaches identify environmental problem which relates with periodic change in land use and land cover, erosion phenomena and variation in climate which are mainly responsible for imbalance of ecosystem and causes an adverse impact on flora and fauna of the region. Due to erratic nature of precipitation and changes in temperature on account of climate variability, the ecosystem changes and ultimately the hydrologic cycle is affected. Natural and human interventions also contribute to the alternatives which may lead to erratic precipitation, excessive humidity, cloud burst downpour, extreme aridity, flood, more surface runoff, excessive weathering of top soil surface and drought etc. Moreover, a region's climate plays a significant job to determine the occurrence of water for the ecosystem and ultimately for the uses for human being.

Due to the rising population of India optimization of water resources for mitigating future is need of the hour. According to the National Water Policy of India (2012), limited national resources like water which is primary need of life, livelihood, food reliability and for sustainable development. The report emphasizes on the planning and development of water resources sector for their judicious utilization by the Ministry of Water Resources Govt. of India (presently known as Ministry of Water Resources, River Development & Ganga Rejuvenation). India accounts for 15% of the world population and about 4% of the world water resources. One of the solution to solve the country's shortage of water is by interlinking of the rivers adopting the principle of inter-basin water transfer. However, this requires huge resources in terms of money and manpower and other physiographic challenges. The most noteworthy phenomenon in a watershed is the evaluation of water quality and quantity which is attributed to changes in land use within a watershed. The hydrologic cycle get affected with changing land use. This further changes the infiltration rate, recharge into the aquifer, and finally the base flow. (Wang etal., 2006) and the surface runoff of the basin annually (Costa etal., 2003).The rising population coupled with unplanned urban growth caters the change in land use and land cover. With time this further results in water stress and scarcity in a region. To overcome this constraints, periodical integrated planning, development and management of water resources is required to meet the water demand.

Prediction of runoff at a particular place in a watershed can be done along with sediment and chemical yields by using sustainable model in a GIS methodology. It can also be employed to determine the aspect of flooding & also used for operation of reservoir and predicting the water borne contamination(Jain et al., 1996). The hydrologist and the practising water resources engineers plan, investigate and develop water resources through hydrological modelling which integrates the Hydrologic system by simulation technique (Schultz, 1993).

Surface runoff generated from a watershed can be assessed by different geographic tools such as GIS. The impact of such runoff depends upon the following:

1. Rainfall characteristics such as spatio-temporal variability, intensity, distribution and magnitude.
2. Watershed characteristics: These are like slope, drainage density, topography, vegetation, top soil and shape.
3. Climate factors that affects evapotranspiration.

Watershed conservation activities tends to alter soil properties, vegetative cover and many times the effective topography of watershed. These conservative measures have an influence over surface runoff potential of the watershed.

Drainage basin is the geological units of the globe which drains into a common outlet. The basin area integrates all the physical and hydrological processes. These processes can be studied in a defined area for processes like rainfall-runoff, recharge, surface water flow, evapotranspiration, groundwater flow etc. inside the basin. To represent the natural processes mathematically, hydrological models are developed which requires basic understanding and effort to compute the physiographic characteristics. Models are also helpful in long term predictions where the data availability is insufficient(Lenhert etal., 2002).

The complex process rainfall-runoff relationship is being assessed by simulation of hydrological models and the distribution with respect to space and time and infiltration taking into consideration of soil, vegetation and climate characteristics. One time series data is taken as input by these models and as output, another time series data is generated by simulating the watershed behaviour for a given input.

1.1.1 Hydrological Simulation in Remote Sensing and GIS

Hydrological simulation is done by collecting data through Remote sensing and GIS techniques where the field data is unavailable or limited(Engman et al.,1991). GIS has the capability to collect data for quantitative description of hydrological processes with sufficient accuracy. Along large river basins, the impact of change in land use and climate are obtained by gathering detailed information on topography, soil, vegetation, geology and weather. However, with every advanced technologies drawbacks are also associated. Therefore, a researcher should judiciously use the remote sensing data while utilizing hydrological models (Peek etal., 1981). Rainfall is one of the important inputs in any hydrological exercises wherein the runoff is estimated with the help of remote sensing in Arc-SWAT interface. Consistent simulation estimates the losses and generate the streamflow by simulating the wetting and drying of a catchment at daily time step. Further the hydrological models were generally utilized for investigating the impact of environmental changes also. The continuous process of hydrological simulation implies that the condition of soil moisture is simulated uninterruptedly. It is observed that the soil moisture state is very important part of stream flow modelling especially large variance in runoff between monsoon and dry seasons.

1.1.2 Impact of Land use and Land Cover(LULC) Changes

Land cover is the physical condition of the surface of region which quantifies how much of the land surface is covered by forest, grassland, impervious surfaces and water bodies. Water bodies consist of open water or wetlands. Land use reflects how the landscape is changed by human activities if assessment is made on temporal basis. Land use at any region indicates how the land is being used i.e., from agriculture land to residential, or a change in category of use. Shift in local or regional climate condition might be obtained by detecting the change in land cover on long term basis, which happens in terrestrial global monitoring. The hydrologists are often interested in finding the effect of LULC changes on the outputs of hydrological model of a basin. The altered discharge due to the effect of LULC change in helpful in developing better management of water resources in a basin. (Ayana et.al, 2014). The degree and type of change in land use influences the runoff, the rate of infiltration, soil erosion and sediment load transport and change in soil nutrients. The change in LULC will affectthe severity in flood frequency, fluctuation in base flow and alteration in daily and monthly runoff rates. The LULC is the primary factor and it is more dominant than the climate in determining the discharge in a time series. Hence taking the LULC for the basin at two different periods for runoff generation at the basin scale will give a clear picture of the basin hydrology by the influence of LULC.

In the present research, the Soil and Water Assessment Tool (SWAT) model is applied for simulating the quantity of surface water i.e., runoff on the effect of change in land use in different years for ascertaining the hydrology of Budhabalanga river basin based on catchment characterises. Two of the major projects like Kamta Irrigation Project and Banktira Irrigation Project are under active consideration and construction. Survey is under progress for taking up the project which has been technically sanctioned by the Central Water Commission. Also the minimum downstream is assessed from observed and computed flow by running SWAT model.

1.2 Research Gaps

On the basis of review of different literatures the following shortcomings have been found.

1) Most of research works have been done on large basins, State and Country regarding land use and variability in climate impact on stream discharge incorporating large landscape. But a few researchers have done their work in a small sub-basin or watershed.
2) Limited studies have been performed considering land use and climatology factors on hydrology of a basin by ascertaining the trend for precipitation series.
3) It is observed from literature review that the changes in LULC has been considered taking into old satellite imagery but not taking the recent images which are needed to have more precise understanding.

1.3 Need of the Study

1) Small sized catchments are often ignored for hydro-meteorological investigations
2) The area of interest is prone to hydrological extremes and hence, urges for extensive research and monitoring
3) To study the impact of the LULC changes for assessment of river discharge due to growth of population and rapid urbanisation for better management of watershed.

1.4 Objectives

The major objectives of the study are:

1) To carryout trend analysis of meteorological variables over Budhabalanga river basin.
2) To assess the impact of changes in land use and land cover by using RS and GIS techniques.

3) To evaluate the workability and performance of the SWAT model against daily and monthly runoff.
4) To estimate the effect of LULC changes and climate variability in river discharge in the basin using SWAT model.

1.5 Organization of Thesis

This dissertation report divided into six chapters, excluded references. The brief information about each are given in next sections.

Chapter - 1 is about the introduction part of hydrological modelling of the Budhabalanga River Basin which includes surface and sub-surface flows, changes in land use and land cover of the basin on application of Remote Sensing and GIS techniques along with the objective of study for the present work.

Chapter - 2 enumerates the Review of Literatures pertaining to the hydrological modelling of different basins in Indian Sub-continent and rest of the World to ascertain the Research Gaps in such a study.

Chapter - 3 is about the Geographical position the study area, morphology, geology and the climatologically factors like precipitation and temperature.

Chapter - 4 depicts the various methodologies used for the study such as trend analysis of spatiotemporal change of precipitation and temperature in basin. It also describes the use of hydrological modelling by SWAT model in Arc-Swat interface. The simulation, calibration and validation by running the model for obtaining run-off at outlet point along with versatility of model by calculating the efficiency.

Chapter - 5 envisages the output of the simulation of the hydrological model and the results found from the study. The impact of changes in Land use and land cover on hydrology of the basin and the analysis there of.

Chapter - 6 depicts the conclusions obtained from the results of the run of model for agricultural planning and water resources development considering the spatiotemporal distribution of weather parameters like rainfall, temperature maximum, temperature minimum and evapotranspiration under climate change condition.

CHAPTER 2: LITERATURE REVIEW

2.1 Background

Literature review is a key segment of any research/project that describes the research works carried out in the past, their outcomes, advancements made through them, their shortcomings and the requirement of future research on those which were left out. Study of spatiotemporal variability of rainfall, temperature gives rise to variation of trend in annual precipitation. Application of SWAT model for prediction of impact of land use changes on runoff, sediment yield and for future prediction of the hydrology of basin.

2.2 Study carried out on Trend analysis of Weather parameters

Pandey, B.K. et al., (2018) evaluated the change in temporal trend of reference evapotranspiration (ET_0) and precipitation and also its spatial variability over Narmada river basin, India. Monitoring stations were selected for evapotranspiration and precipitation for a duration of 102 years. Mann-Kendall test and Spearman Rho was conducted for detection of trend and Sen's slope estimator was used to find the percentage change for the time series. Stations showed positive trend for evapotranspiration where as 8% of the stations showed substantial downward trend for mean annual precipitation. Change point for precipitation was located by implementing Buishand's and Pettit's test. Due to temporal changes annual mean precipitation was brought down by 9% in upper part where as it was increased by not more than 5% in lower part. The annual evapotranspiration increased by 4-12% in majority of the area.

Rezaei,E. et al., (2013) examination states edit changes as an adjustment procedure to environmental changes. In his examination considered year 1070 - 2005 as a pattern period and for to future time approaches 2011 - 2013 and 2082 - 2099 from two scenarios A2 and B1 and GCM models downscaled to every day scale by LARS - WG5. The yield information is utilized as a part of DSSAT-4.5 (DSS show) which was adjusted and tried for information from various field tests in the area. In his analysis watched that invert connection amongst temperature and Biomass for both pearl millet and maize. The Biomass yield indicates more receptive to span of phonological stage from colourful start to end of leaf development in this stage additionally discovered negative interrelationship between mean temperature and biomass field yield which endured more in Pearl millet than maize this outcomes likewise supported in trim model for evaluation. In light of biomass yield and WUE in future situation edit substitution i.e. Maize by pearl millet is best fit as measure for expanding feed generation in the district.

Rejani, et al., (2009)assessed groundwater bowl in Odisha, India which confronting risk of ground water withdrawal and sea water intrusion. Ideal pumping timetable, trimming designs and relating groundwater condition for three situations (wet, typical and dry) were worked out utilising simulation - advancement demonstrating methods. For the examination to advancement models all around created and utilized amid non-storm period. Non-linear pressure driven administration show for ideal withdrawal and straight enhancement demonstrate for astounding trimming design in the wake of adjusting and approving groundwater stream reproduction. The ground water level enhanced significantly under the ideal water powered condition as per the current situation. In dry season the ground water level under the current withdrawal design and ideal pumpage demonstrates that the non-rain storm withdrawal will not surpass the phenomenal drawage without recuperative measures.

Mishra A. K., (2014)examined water and nourishment security are the key issues under environmental change as both are exceptionally inclined to persistently fluctuating atmosphere designs. It is anticipated that the mean worldwide temperature might increase by 1.4-5.8^{0}C and there would be ground breaking lessening in crisp water stock and agronomic yield before the finish of 2100. In sub-Saharan Africa by 2050 the precipitation may exhaust by 10% which thus would diminish the stream by 17%.

Mondal et al., (2012)carried out analysis of trend of daily rainfall over North-East Cuttack for 40 years (1971-2010), using MK and Sen's slope estimator test. The study indicated rising and falling trends of precipitation in different months of the year. Overall trend was not significant.

Longobardi and Villani (2010)analysed trend of seasonal and annual precipitation over Southern Italy, collected from 2011 stations from 1918-1999 using MK test. They found the trend predominantly appeared negative both at seasonal and annual scale, except in the summer season which is found to be positive (increasing).

Duhan and Pandey (2013) studied the spatial and temporal variation of rainfall for 45 districts in the state of Madhya Pradesh, India. The author has used over 102 years of data. The analysis was carried out on annual and seasonal basis using MK and Sen's slope test. They observed diametrically opposite trends over most of the stations. The percentage change in annual precipitation was 14.88% for 1901-1978 whereas it was (-)12.99% after 1978.

Kumar et al., (2018)investigated the trends in temperature and precipitation using CMIP5data. 20thcentury climate simulations using MK and Sen's slope test. They observed that the global land-average temperature trend was increasing. They also estimated the global precipitations trends distributed (spatially) in both the models.

2.3 Hydrological Model Studies (SWAT) under Climate Change

Rostamian et al., (2008)applied SWAT model over Beheshtabad and Vanak watersheds of Karun catchment, Central Iran to simulate runoff. They observed the discharge data and estimated runoff from the post calibrate model which possessed excellent agreement.

Ayana et al., (2014) applied SWAT model over Fincha watershed, Bluenile river to estimate the effect of land use and management practices on runoff and sediment yield. Output of the model had given precise estimates of runoff and yield of sediment as obtained from the calibrated results.

Patil et al., (2014)simulated stream flow in Bhima river basinusing SWAT model. The results showed acceptable agreement between computed and observed discharge.

Narasimlu, B. et al., (2015) used SWAT hydrological model in Kunwari river basin in India for effective water resources management for sustainable agriculture and flood control management. SWAT model is simulated for 1987-199 with initial 3 years as a warm up period 1987-1989 and six year period for validation from 2000-2005. Calibration of model shows R^2 = 0.77 and (NSE) Nash-Sutcliffe efficiency is 0.74 and validation of model gives shows R^2 = 0.71 and NSE=0.69. Validation process is through by using sufi-2 algorithms which estimates susceptibility and uncertainty of hydrological model. The outcome of sensitivity and uncertainty of investigation using SWAT and sufi-2 pinpoints model is applicable for stream flow forecast in basin. Simulated results are fitting with the site observed data hence suggested to use the model. LULC and climate change effects on management of water resources trigger practical measures such as agricultural and soil water management. This helps in mitigating and coping the recurring drought and floods in the region.

Shrestha et al., (2015)analysed the impact of land use changes on runoff and sediment yield by using SWAT model in Da River Basin of Hoahbinh province, Northwest Vietnam. Output of simulation exhibits that SWAT is adequately capable to determine the yield of sediment and runoff, which were affected by vegetation significantly.

El-Khoury et al., (2015) investigated the climate change along with land use change situation brought about a slight diminishing of water yield contrasted with climate change situation alone in light of some augmentation delivered by the land use change. Regular change, diminishing in water return under the environmental change situations are watched for all seasons with more articulated changes in winter and spring those are the primary stream seasons. Nearly, spring has the biggest diminishment in water yield by -(23.7%) which is larger than yearly reduction. Land use situation indicates increment in water yield for every one of the seasons with biggest increment in harvest time of 3.4%. The CC + LU situation ventures comparative diminishing of water yield as that of CC situation.

Kumar, P. et al., (2015)evaluated the influence of changed climate over the Subarnarekha basin on water balance components. The SWAT mode setup was done, and then discharge is simulated using the observed data. Mode performance was assessed for monthly period by help of statistical parameters. The model performance was found in good agreement with respect to the computed and observed data.

2.4 Summary

All the available literatures based on the topic has been discussed in the literature review chapter to identify the research gap and existing techniques.

Further, in the next chapter entitled **"Study Area"** will give detailed information about Geographical Information and Morphological characteristics' of stream network of Budhabalanga river basin.

CHAPTER 3: STUDY AREA

3.1 Geographical Location of Study Area

The Budhabalanga river originates from Similipal hills located in Similipal National Park in Mayurbhanj district and flows within the two districts viz. Mayurbhanj and Balasore before draining into Bay of Bengal. It is a sub-basin of Subernarekha River Basin which flows on the northern part of Odisha. The Budhabalanga sub-basin is located between 21°29′ to 22°19′ N latitude and 86°06′ to 87°05′ E longitude. The study area covers an area of 4381 km^2. The climate of the basin is characterized as summer from March to May with monsoon season from June to September having some rains in post monsoon season too. Sometime the region witness cyclonic storms due to depression in the Bay of Bengal. The geological formations taking place in the basin are of Tertiary age and alluvium plains which cover the basin. The Subernarekha River flows through the states of West Bengal, Jharkhand and Odisha and is an interstate basin. The basin lies 49%in Jharkhand, 13% in West Bengal and 38% in Odisha before flowing into Bay of Bengal. The river length is approximately 175 kilometers and its major tributaries are Kalo, Sunei, Katra and Gangahar. The basin has an outlet point near Govindpur (NH5 Road Bridge) which is present in Balasore district of Odisha and river gauging station is maintained by the Central Water Commission for measuring the flow discharge and gauge readings. The location map of the study area is shown in Figure 3.1.

3.2 Topography

The Budhabalanga river (called old Balanga locally) starts from the Similipal hills of Similipal National Park and passes through Barehipani Water Falls, the second highest waterfall in India. Then it proceeds further in North direction and flows in the village Karanjiapal in Bangiriposi Block of Mayurbhanj District. The highest bed level of river is 1108 m and the lowest level of bed is 6m at the downstream of the basin. The digital elevation model of study area is shown below in Figure 3.2. The minimum elevation of the catchment is 5 m and the maximum elevation is 1189 m above mean sea level.

3.3 Climate

South-West Monsoon generally influences the basin, which approaches in the month of June and ends in October. The average annual precipitation is around 1650 mm in the sub-basin. Tropical climate exists in the basin having hot summer and mild winter. There is a variation of 40.5 ^{0}C (May) to 9.00 ^{0}C (December) in the mean monthly temperature.

s

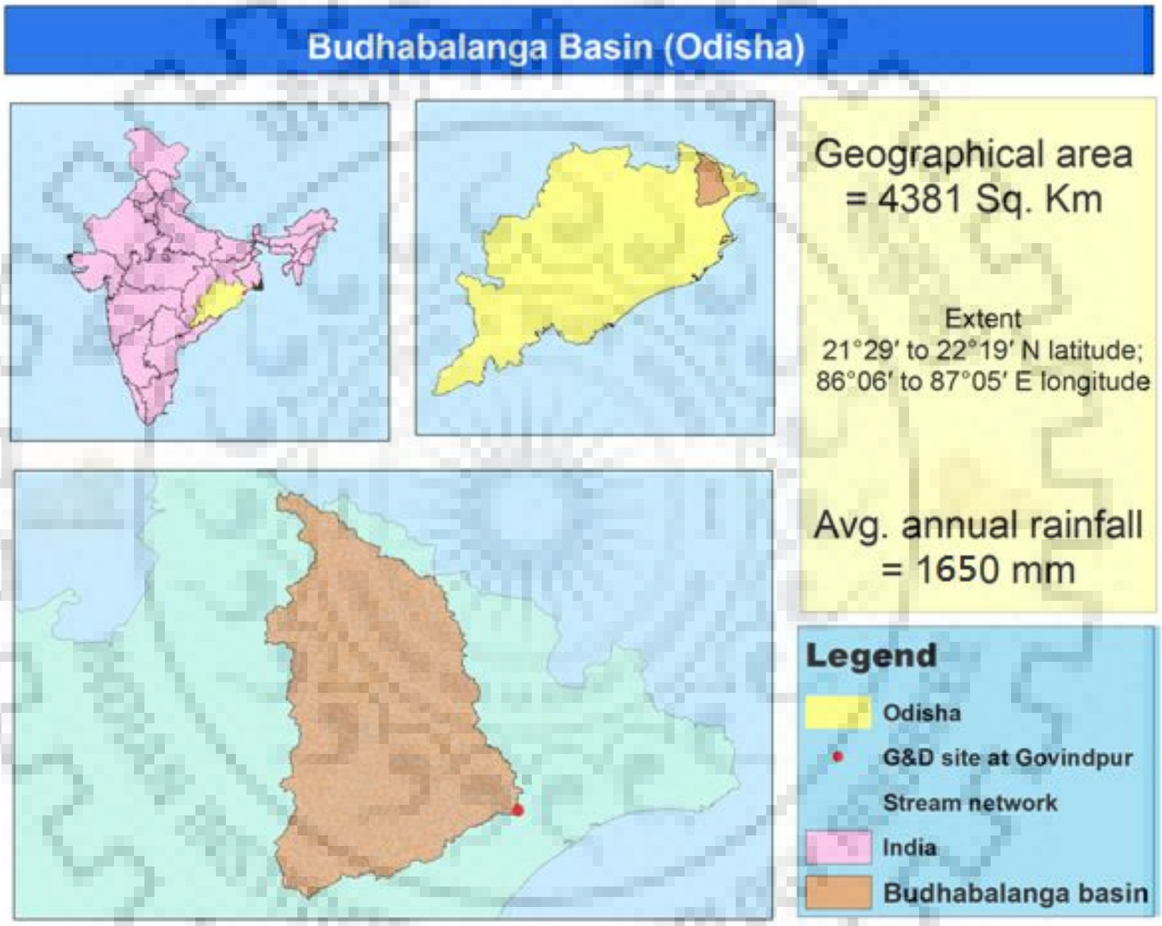

Figure 3.1. Location map of Budhabalanga basin

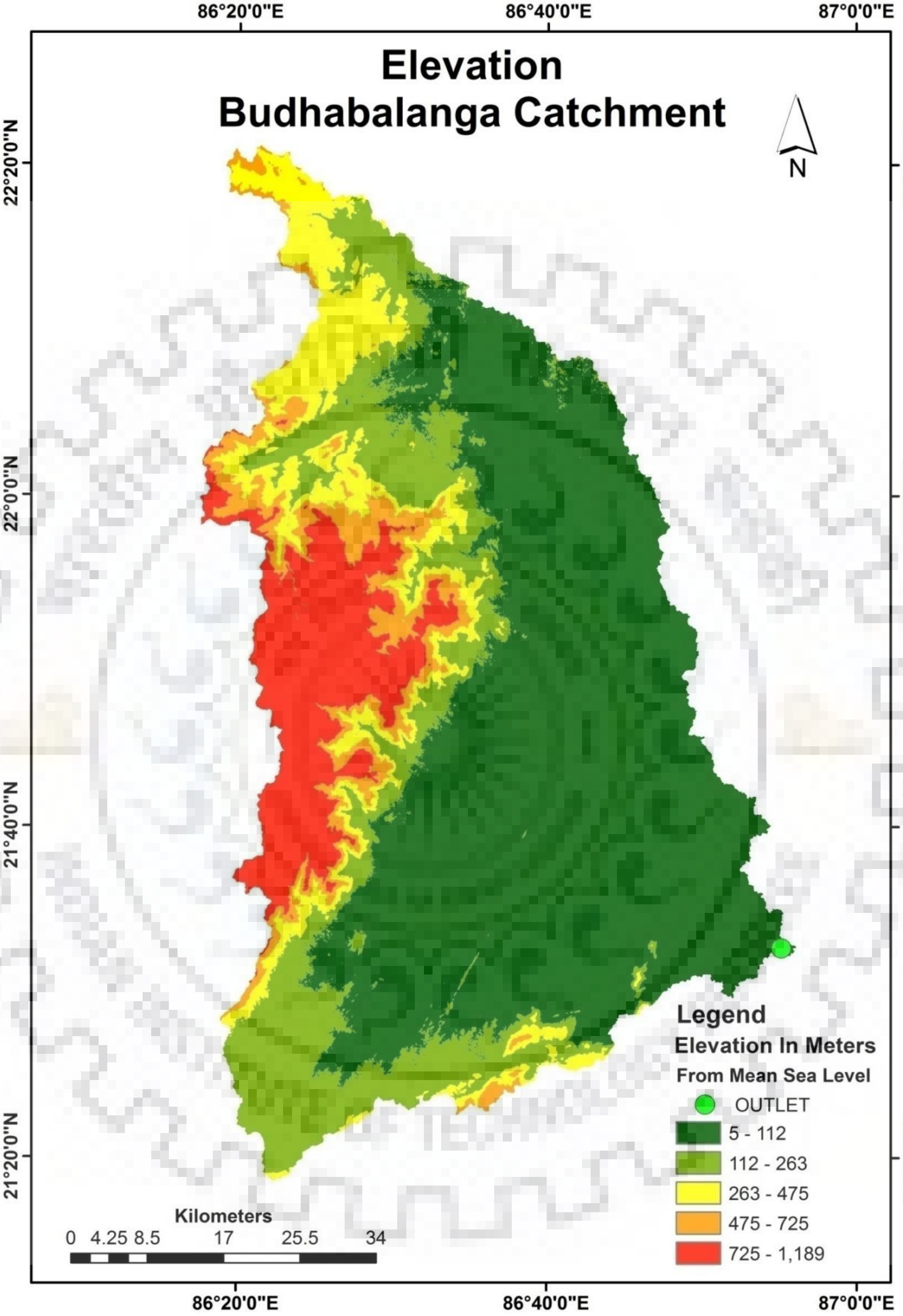

Figure 3.2. Elevation map of Budhabalanga basin

3.4 Rainfall

The average annual spatial distribution of rainfall is varying from 2255 mm maximum in the Similipal hill region to a minimum rainfall of 1329 mm in arid region. Over the study area the mean annual precipitation is around 1700 mm which is collected during south-west monsoon season spanning from the month of June to month of September. Considering thirty years rainfall data the annual average rainfall of seven rain gauge stations, the average minimum annual rainfall in the basin is 1284 mm in the year 2000 and maximum annual rainfall is 2324 mm in the year 2013.The monthly and annual average rainfall of seven raingauge stations inside the catchment area is shown in the Table 3.1.In the thirty years period, the minimum annual rainfall in the basin is 1173mm and the maximum annual rainfall is 2324mm which occur in the year 2010 and 2013 respectively. The monthly precipitation series from 1988 to 2018 is represented graphically in the Figure 3.3 below.

Table 3.1: Monthly and annual average rainfall data for seven rain gauge stations inside the catchment.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1988	0.00	25.86	10.83	99.81	34.56	393.23	245.34	239.94	263.47	89.26	6.50	0.00	1408.80
1989	0.00	1.14	18.57	9.06	195.57	340.60	305.04	396.79	173.74	78.43	0.00	0.00	1518.94
1990	0.00	92.39	138.69	43.09	139.23	281.90	235.20	323.17	367.97	239.87	62.46	4.91	1928.87
1991	30.09	8.29	49.29	55.83	81.07	144.30	290.23	390.46	134.63	103.09	10.27	2.70	1300.23
1992	21.91	22.36	0.00	9.63	85.09	250.23	343.40	340.83	201.03	82.46	0.00	0.00	1356.93
1993	0.00	0.00	5.00	91.40	110.86	308.74	326.47	362.17	367.87	56.10	3.43	0.00	1632.04
1994	13.09	49.56	16.71	115.77	85.49	358.03	521.73	328.57	285.34	43.44	3.43	0.00	1821.16
1995	37.09	21.57	46.57	15.57	339.94	191.06	195.67	364.76	264.26	184.64	262.69	0.57	1924.39
1996	30.49	13.66	0.74	20.86	69.94	307.77	373.46	397.60	56.40	139.23	2.74	0.00	1412.89
1997	17.71	10.00	68.71	120.43	107.41	382.34	295.84	540.50	344.41	57.46	27.20	53.63	2025.66
1998	61.03	32.40	58.46	51.77	106.60	128.46	214.83	151.41	297.59	117.63	58.54	0.00	1278.71
1999	0.00	0.00	0.00	3.60	186.67	290.36	261.29	330.03	356.77	333.29	19.74	0.00	1781.74
2000	0.17	45.13	0.00	56.26	119.26	298.31	265.06	240.44	227.23	27.94	3.74	0.00	1283.54
2001	0.17	5.94	15.14	65.31	143.96	242.14	454.66	274.99	155.44	254.44	14.11	0.00	1626.32
2002	21.29	0.00	43.50	17.91	58.49	204.41	110.04	287.54	372.40	90.31	32.34	0.00	1238.24
2003	0.00	4.57	40.80	40.31	59.97	225.40	320.00	245.21	141.66	477.09	27.26	13.83	1596.10
2004	0.00	0.34	6.17	61.46	69.97	225.94	259.63	432.51	175.20	243.74	0.00	0.00	1474.97
2005	12.43	8.66	91.93	61.56	114.26	198.86	320.09	229.46	397.29	324.29	0.00	0.57	1759.37
2006	0.00	0.00	25.86	28.74	137.71	229.14	345.16	574.80	435.99	24.49	34.17	0.00	1836.06
2007	1.57	77.77	16.86	47.54	79.94	248.91	492.40	440.54	564.57	23.74	51.31	0.00	2045.17
2008	0.00	0.00	6.00	0.00	183.33	104.77	311.03	219.00	239.11	183.67	19.89	0.00	1266.80
2009	0.00	0.00	6.00	0.00	183.33	104.77	311.03	219.00	239.11	183.67	19.89	0.00	1266.80
2010	0.00	0.00	14.23	6.40	190.20	97.86	174.29	209.54	294.47	152.59	7.40	26.39	1173.36
2011	2.63	9.06	12.71	64.79	149.26	437.89	118.74	376.49	479.57	8.31	0.00	0.00	1659.44
2012	64.20	5.17	0.00	97.34	54.87	148.93	250.80	284.23	206.31	39.50	24.03	21.53	1196.91
2013	0.66	6.46	4.94	80.51	244.97	198.20	374.63	410.51	292.09	711.49	0.00	0.00	2324.46
2014	31.60	58.54	43.31	23.20	199.10	148.89	402.49	389.70	214.46	101.74	0.00	30.49	1643.51
2015	28.77	0.14	31.20	128.54	57.53	282.23	435.37	187.50	137.17	9.57	0.00	30.49	1328.51
2016	9.40	56.63	9.06	35.06	114.03	194.30	235.43	301.50	282.57	116.51	39.74	0.00	1394.23
2017	0.00	0.00	79.21	26.34	146.54	156.51	371.29	314.33	221.50	224.07	45.03	0.97	1585.80
2018	0.00	0.14	0.29	195.27	145.41	249.74	305.26	340.71	0.00	0.00	0.00	0.00	1236.83

Highest rainfall (red); lowest rainfall (Green)

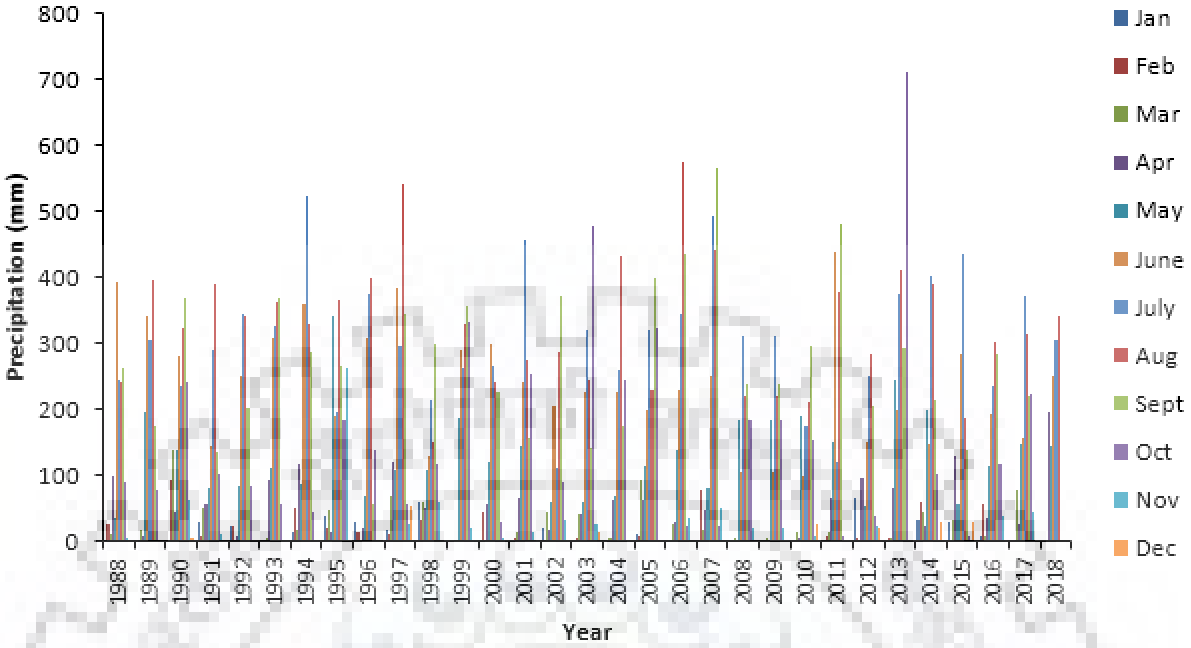

Figure 3.3 Monthly precipitation in the study area (Period 1988-2018)

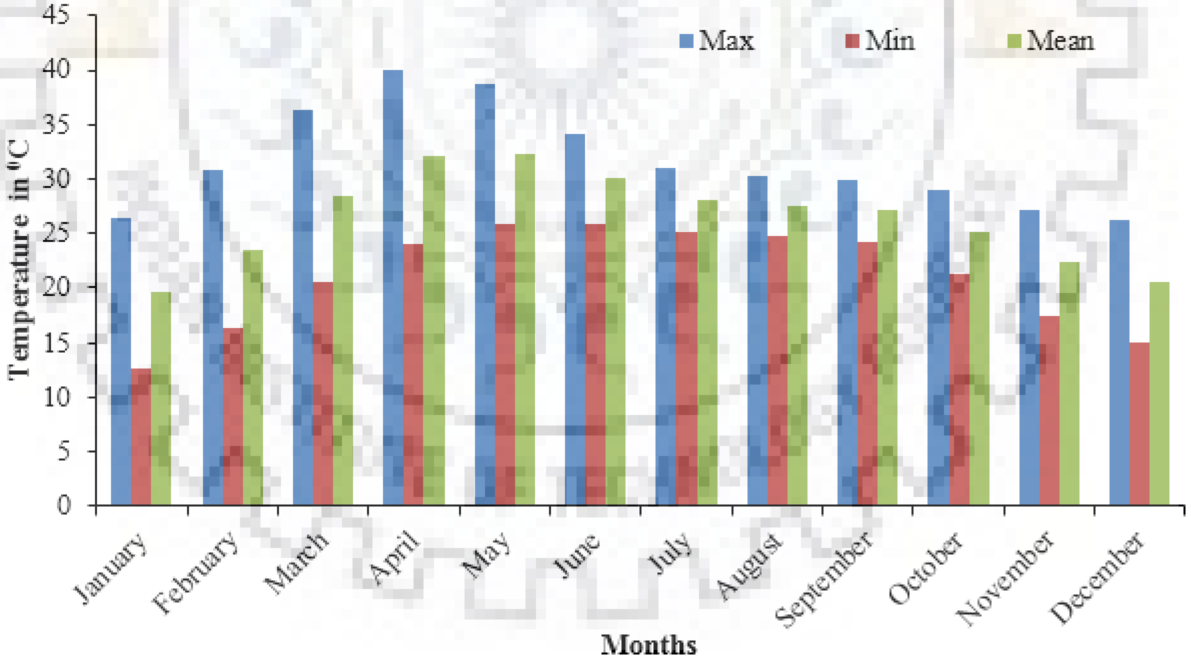

Figure 3.4 Average monthly maximum, minimum and mean temperature

3.5 Soil

The study area is comprised of two categories of soils namely loam and sandy-clay-loam soils as per the Food and Agriculture Organization of the United Nations (FAO) shown in Figure 3.3. The main composition of Loam(I-Ne-3729) is Clay-33%, Silt- 25%, and Sand- 41% in Sand clay loam(Lf-96-2ab-6668) and (Nd-50-2ab-3819) is Clay-23%, Silt- 25% and Sand- 51%. In sand clay loam (Lf-96-2ab-6668) the composition of Clay- 23%, Silt- 25%, Sand- 51% and in Sand clay loam (Nd-50-2ab-3819) is Clay- 23%, Silt- 27%, Sand- 49%. Both the soils fall under medium textured soils, the infiltration rate for Clay loom is 0.6-0.8 cm/hr and sandy clay loam is 1.2-1.8 cm/hr (Varshney et al., 2009). Fine textured soils are the soils with similar particles and thus they have small pores which are more difficult for air and water to penetrate. This is one of the reasons for which medium textured soils are better soils for crop production than fine textured soils even though the fine textured soil can store more water per unit volume.

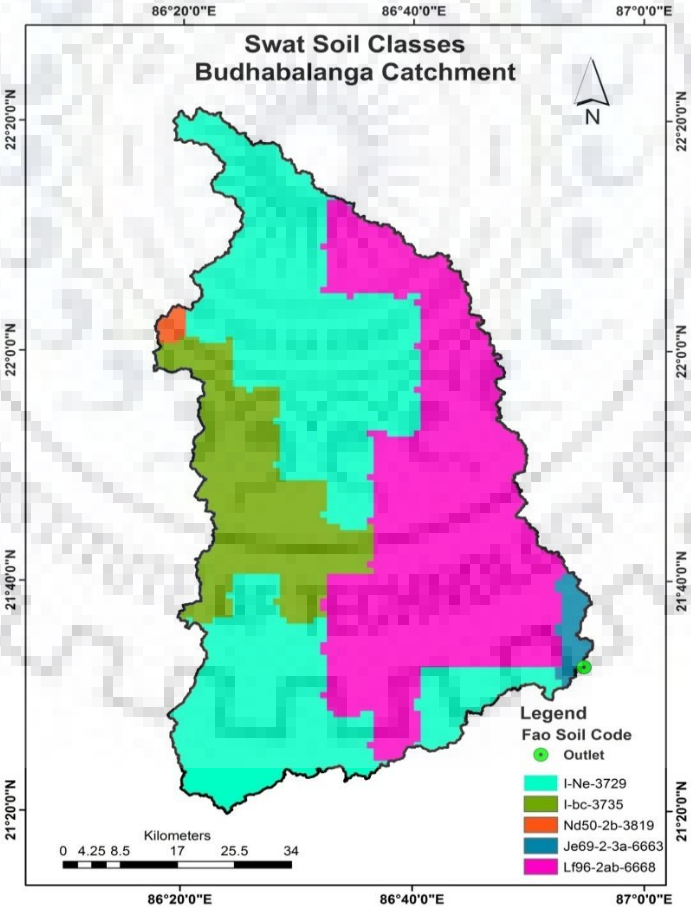

Figure 3.5:Soil map as per FAO classification

3.6 Data used

In Table 3.2 data used for analysis of work in the catchment area is presented. The use of data has been explained in detail in the respective chapters along with objectives. The description of data, range and procured source is also mentioned with resolution.

The Digital Elevation Model(DEM) is of 30m resolution which is downloaded from Bhuvan website for the study purpose. BhuvanCartosat-I provides high resolution DEM. However to make sure higher accuracy happens in elevation data, higher spatial resolution may not be sufficient. With latitude and longitude, DEM represents altitude of earth’s surface, i.e. X,Y in horizontal and Z in height.

Table 3.2: Details of data acquired and source of acquisition for Budhabalanga River Basin (Odisha)

S.N	Description	Data Range/Resolution	Source
1.0	Digital Elevation Model (DEM)	30m	www.bhuban.nrsc.gov.in
2.0	Soil Map	1:150000	FAO Website http://www.fao.org/soils-Portal.
3.0	Land Sat- 8(OLI)	30m	https://earthexplorer.usgs.gov
4.0	Rainfall,TemperatureMaximum &Temperature Minimum	Station Data	www.srcodisha.nic.in
5.0	Relative humidity,Windspeed and Sunshine hours	1988- 2014	India Meteorological Department (IMD)
6.0	Stream Flow Measurement	1988-2014	Central Water Commission, Gauging Station at Govindpur.

3.7 Summary

Chapter 3 discussed about the geographical details of the Budhabalanaga basin including the climate, rainfall, soil, and others details.

The next chapter will briefly provide the approach and methodologies followed in trend analysis and LULC effect on the stream flow.

4.1 General

The details of methods used for the research work pertains to precipitation and temperature trends in the entire study area by applying Sen's slope estimator (SSE) test and Mann-Kendall (MK) test to find out the spatio-temporal variation of weather parameters over a period of thirty years. The study also simulated runoff yield at outlet of catchment by using SWAT simulation model. SWAT- CUP tool is used for calibration and validation. The study also assessed the impact of land use changes over the hydrology of the basin. The future prediction of flow at different required project sites were also ascertained in the study. The approach and methodology adopted to achieve the objectives are discussed below.

4.2 Trend analysis of weather parameters

4.2.1 Mann-Kendall Test

Weather parameters like rainfall, maximum temperature and minimum temperature of seven stations have been examined for the periods from 1988 to 2018.The weather parameter data is obtained from IMD on daily basis, the data analyzed is tested with Mann-Kendall on annual and seasonal basis viz. pre-monsoon season (from March to May), monsoon season (from June to September), post-monsoon season (from October to November) and winter season (from December to February).

The Mann-Kendall test is a statistical test that is generally used to study the temporal and spatial variation of precipitation, temperature in a continuous time-series(Yue and Wang, 2004). It is also used for detecting a trend in hydro-climate time-series which is a non-parametric test. Both linear and non-linear trends in a time series is determined by this test.

For a time series x_i ranked from i=1,2…n-1, and $x_j$ranked from j=i+1, 2...n the trend test is applied. For example x_i is used as a data point and is compared with every other data point x_j such that

The Kendall statistics ‘S’ is estimated as $$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} Sgn(x_j - x_i) \qquad \ldots(4.1)$$

The variance of the statistic ‘S’ is defined by

$$Var(s) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{n} t_i(i)(i-1)(2i+5)}{18} \qquad \ldots(4.2)$$

where, t_i denotes the number of ties till sample i.

The test statistics z_c is estimated as

$$Z_c = \begin{cases} \dfrac{S-1}{\sqrt{Var(s)}}, S > 0 \\ \dfrac{S+1}{\sqrt{Var(s)}}, S < 0 \end{cases} \qquad \ldots(4.3)$$

4.2.2 Sen’s Slope Estimator Test

At times when there is a linear trend present in a time series, the true slope can be estimated with the help of an easier non-parametric procedure developed by Sen (1968). With the help of Eq(4.4)for the N pairs of data the slope estimate is first computed.

$$Q_i = \frac{x_j - x_k}{j-k} \text{ fori=1,2,3,.......N} \qquad \ldots(4.4)$$

Where $x_j$and x_k are values of data at time instances j and k (j>k) receptively. Meridian of these Nvalues of Q_i is Sen’s estimator of slope. If N is even, then Sen’s estimator is computed by

$Q_{med}= [Q_{N/2}+Q_{(N+2)/2}]/2$ …(4.5)

andif N is odd then Sen’s estimator is computed by

$Q_{med} = Q_{(N+1)/2}$ …(4.6)

Finally, $Q_{med}$is tested by a two sides test at 100(1-α) % confidence interval and true slope may be found by the non-parametric test.

4.3 Hydrological modelling using SWAT

Soil Conservation Service Curve Number (SCS-CN) method, developed by Soil Conservation Services(SCS) of USA 1969, which is based on the Hortonian overland flow generation mechanisms makes SWAT model to a semi distributed one. The model predicting the surface runoff from watershed are based on Natural Resources Conservation Services (NRCS) curve number (CN) equations. In prediction of surface runoff after excess infiltration at basin, catchment and watershed scale. SWAT model uses SCS-CN method for simulation therefore is extensively used worldwide due to its simplicity and reliability (Kumar et al., 2016).

A continuing effort for nearly in modelling conducted by USDA Agricultural Research Service (ARS) has resulted in the Soil and Water Assessment Tool (SWAT) model.

Calibration, Sensitivity and Validation of flow of stream with related hydrological studies, variation in hydrological cycle due to climate change impact, loading of nitrates, phosphates, and the other chemical wastes from fertilizers, evaluating the results by comparison of different models are the relevant categories on which SWAT application are based. In ungauged spatially watersheds, SWAT model continuously on time basis in a daily-time setup is planned to predict the quality and quantity of water, chemical yields from agricultural and sediment transport in the flow using low cost satellite data.

The sub-watersheds of a watershed are subdivided further into hydrological responsive units(HRUs) which is characterized by homogenous land-use, slope and properties of soil for simulation in SWAT model. The HRUs are spatially not identified inside a SWAT simulation rather they represent the percentage of the sub water shed area. On the other hand, soil type, dominant land use and management are the main characteristics of a subdivided watershed. The initial version of SWAT was developed in early 1990s.

The energy and moisture inputs, like daily rainfall, Maximum/Minimum temperature of air, Solar-radiation, Speed of wind, amount of water content in atmosphere in terms of relative humidity are all climate driven and are provided in hydrological cycle. To generate simulation of all these data at run-time from monthly observed statistics by reading the observed data directly from files are achieved in SWAT model. When temperatures are very low like below freezing snow, to study the impacts of movement of water and the rate of decay of residue in soil, the temperature of the soil is computed. The intercepted precipitation which is stored on the leaves and later evaporated are canopy storage, percolation through the top soil i.e., infiltration, flow of excess infiltrated water through surface taking into soil moisture root zone depth, evapotranspiration, capillary rise, lateral flow, tile drainage, soil profile with a redistributed profile, pumping (if any) causing consumptive use, return-flow and seepage from ponds, surface water-bodies and tributary channels leading to under water recharge of shallow or deeper aquifers of hydrological process are simulated on the time basis in SWAT model. All kinds of land cover are simulated by using a single plant growth model in SWAT and annual perennial plants are differentiated. The removal of biomass with yield production are analyzed using plant growth model. The inflow, outflow and precipitation on surface, seepage from the reservoir bottom, evaporation and water-flow diversions defines water balance for reservoirs (Arnold 2012).

Partition of watershed into subunits is the initial step in setting-up a watershed simulation mode. Various sub-units or objects used in the portion of watershed are defined in SWAT and are given as below,(Neitsch et al., 2002).

Sub basins are the first level of subdivision in watershed modelling. Geographical position of outflows from different sub basins in the watershed are related to each other in the sub basin e.g. outflow from sub basin #12 enters into the sub basin #9 and so on. Sub basins are characterized to flow within the boundary of a watershed and also the whole area inside sub-basin flows from sub-watershed to sub-watershed and finally to the sub-watershed outlet. Boundaries of the watershed are obtained by grid cells area in satellite imagery thus delineating the sub basin in watershed. Grid cell areas can be calculated and hence becomes an appealing approach for sub basin delineation. Many spatial data i.e. DEM, NEXRAD, LANDSAT8 are in grid cell thereby are appealing approach in watershed delineations. The routing reaches and topographic flow paths are not discredited by the grid cells as the delineated sub watershed (Neitsch et al., 2002)

Hydrological responsive units are the subdivided area of a sub basin. The unique attributes such as land use, management and soil are possessed incorporated by HRUs in SWAT as a part of HUMAS (Hydrological Unit Model for the US)project. HRUs doesn't resembles the area of the field, rather it represents the area of a particular land-use management and soil present in the watershed and slope of topography. As the individual class such as a specific land-use management might spread throughout a sub-basin, these areas are grouped together in forming one HRU. Running a model by grouping/lumping of all identical soil and land-use areas into one single HR Unit will always simplify the run process of a model. Practically individual fields cannot be simulated (Neitsch et al., 2002).

Reach or Main Channels: Each sub-basin is related with a single reach or a main channel in a watershed. Sub basin wise loadings are entered in the channel arrangement of the watershed. Upstream reach outflow reaches the reach segment by passing through all segments of the sub basin (Neitsch et al., 2002).

Ponds/Wetlands/Reservoirs: The creation of HRUs with water as the land use is processed in USGS land use maps by allowing GIS interface. This method should be avoided if possible and ponds, wetlands or reservoirs within a watershed should be used for modelling. Stored water-bodies on network of stream of the watershed are modeled as reservoirs. In common terms manmade structures for storage of water are called reservoirs and naturally occurring stored water bodies are called as lakes. But in SWAT the term reservoir is not meant to define manmade structures. Storage of water measured in terms of abundance will define the term reservoir if storage is abundant and is called as pond or lake. Main channel network will have a larger impoundments compared to that of the main channel network impoundments due to the variation in the size of the channels. Different types of water bodies in watershed may be treated as main channel impoundment and sub basin impoundments, as it is convenient to make use of these two terms for storage input require different file extension. Each sub basin may be defined by two water bodies pond/wetlands. These sub basins can receive only the water entering into within the sub basin- water generating from other sub basin cannot be received. This implies that the water received reservoir are due to network of all upstream channels in the sub-basins(Neitsch et al., 2002).

Point Sources: Water, sediments and nutrients loading from land area in watershed are directly modeled in SWAT. However in large spatial area the loadings to the stream network from sources may be outside the watershed area, these sources are called as Point source. Loading from sewage treatment plant are the most common point source. SWAT has allowance to account for point source loading on everyday or average loading data into the channel. These point source discharges along with loading generated by the land areas are further carried through the channel network to the outlet point (Neitsch et al., 2002).

Ideal areas with runoff, soil and other hydrological behaviour which are hydrological responsive areas in the watersheds are grouped in Hydrological Response Unit and then analyzed individual grouped areas. Based on LULC class, soil properties and land slope condition the HRUs are created for analysis. Spatially varied behaviour of hydrology in a watershed leads to several well demarcated HRUs depending upon Soil categories, LULC and slope parameters, in turn allowing the engineers to study conditions and problem variations in an effective manner. Adaptation of site specific management i.e. on each HRUs can give better information for combating the problems related to individual groups such as LULC, Soil or Water.

HRU based conservation of critical areas in watershed will be helpful to manage areas with specific issues and problems. HRU based analysis is preferred to random area management. Kumar et al., 2016. Collected rainfall data if underestimated, paucity of model calibration where in less number of years were taken into account for calibration and validation are some factors which gives feeble results and also have adverse effect on SWAT hydrological equations.

SWAT is a robust interdisciplinary watershed model with its ability to receive multi-disciplinary inputs and simultaneous simulations of input data on daily time setup by its modelling tools has gained international acceptance as evidence from international SWAT conferences and hundreds of peer-reviewed journals (Gassman et al.,2007).

Presently used hydrological modelling in SWAT 2012 which is developed by incorporating many components, enhanced sub modules and algorithms which features like pre-processing and post- processing tools, the model also supports the widely used remote sensing and GIS interface software's such as ArcGIS SWAT (Arc SWAT). Simulation of stream flows, sediment and loading of natural nutrient in a watershed at spatial level and many input data as soil and water conservation SWAT mode. World-wide in many countries for estimation of discharge as well as soil and water conservation SWAT models extensively used are successful (Narasimalu et al.,2015).

In various study field such as sciences including biosciences, hydrological sciences, structural sciences and weather science, evaluation of uncertainty parameters have gained popularity. Sensitivity Analysis (SA) and Uncertainty Analysis (UA) are very much useful in evaluation of model calibration and validation. Number of input parameters, model complexities as well as large number of iterations are essential for modelling by calibration technique making it a rigorous and challenging process. The uncertainties imposed by variations of model parameters and structures can be effectively reduced by sensitivity analysis and uncertainty analysis. Application of water resources management models such as SWAT are globally accepted only after the model is calibrated and validated. Simulation of stream flow and sediment loads of a river basin are with acceptable accuracies are resulted from SWAT model. Pre-collection of resources data, cautious prediction of uncertainty analysis and calibration are evitable for successful application of hydrological models in practical water resources investigations. The uncertainties calibration techniques are associated with many input parameters, model structures and outputs which makes the model prediction most uncertain hence, it has to be represented with a confidence range. Decision making on management of water resources in hydrological process and other relevant processes are valuable only when uncertainties are estimated and predicted reasonably well. There are many techniques developed for analysis of watershed models by evaluation of calibration and uncertainty, recently developed ones are listed below:

- Markov Chain Monte Carlo (MCMC) Method
- Generalized Likelihood Uncertainty Estimation (GLUE)
- Parameter Solution (Parasol)
- Sequential Uncertainty Fitting (SUFI-2)

SWAT model is linked with all the above four techniques through SWAT-CUP algorithm, by enabling sensitivity and uncertainty analysis of model parameters as well as structure. For management of water resources of a basin Swat model proved to be an efficient model on the basis of model calibration and UA. To obtain high quality calibration and uncertainty results, a minimum number of model simulations is required for the application of SUFI-2 techniques. Narsimalu et al.,2015; Yesuf et al., 2016.

4.4 Physical Modeling (Soil and Water Assessment Tool)

In SWAT Model, the Digital Elevation Model (DEM) is used as the initial parameter for generating slope and drainage based on the pour point (generally known as outlet points method), sub-basin parameters such as slope gradient, slope length of the terrain and stream network characteristics such as channel slope, channel length and channel width are derived from DEM by processing in the SWAT model. The SWAT model requires different soil textural and physicochemical properties such as soil texture, available water content, hydraulic conductivity, bulk density and organic carbon content for different layers of each soil type. For the current study, the National Bureau of Soil Survey and Land Use Planning *(*NBSS&LUP) soil data (1: 250,000 scale) has been used. Note that the soil parameters must be categorized according to SWAT model geodatabase. LULC is one of the most important factors that control the main hydrological behaviour of the catchment and protects it from events such as soil erosion, runoff, evapotranspiration and sediment deposition.

The SWAT model requires daily hydro-meteorological data for simulation of the model. The rainfall, minimum and maximum air temperature, solar radiation, relative humidity and wind speed are the meteorological data provided as inputs in the model. Daily observed stream flow data for seven stations had been used for validating the simulated results. The main steps in the model set-up involved data preparation, sub-basin discretization. HRU definition and overlay parameterization, sensitivity analysis and calibration. Finally, SWAT model has to be set to simulate the various hydrological components

The pictorial representation of the overall methodological flow chart for SWAT model (Calibration and Validation) is shown in Figure 4.1 below.

In SWAT display, the DEM is utilized as the underlying parameter for generating slope and drainage based on the pour point. The other Sub-basin parameters, for example, channel slope, channel length and channel width are obtained from DEM by preparing in the SWAT model. The SWAT requires diverse soil texture and physiochemical properties like soil surface, accessible water content, hydraulic conductivity, bulk density and natural carbon content for various layers of each soil kind.

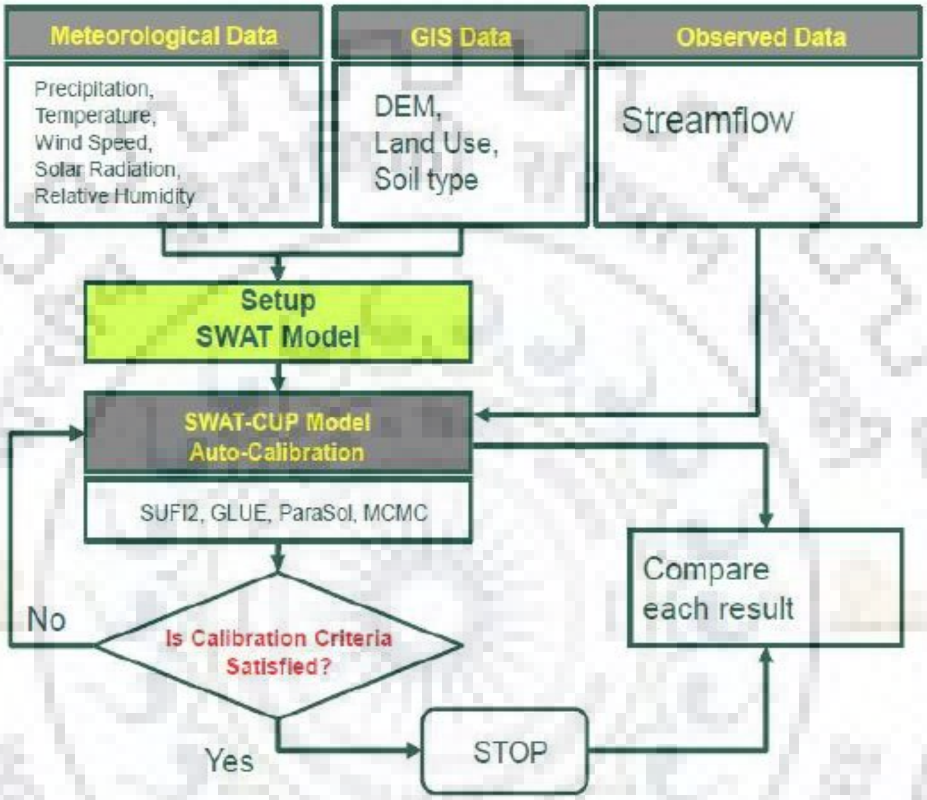

Figure 4.1. Flow chart showing overall methodology of SWAT model

The FAO world soil data of 1:50,00,000 scale is used. The soil parameters are classified based on the SWAT model geodatabase. Land-use/ land- cover is one of the most critical components that control the fundamental hydrological conduct of the catchment and shields it from occasions like soil erosion, runoff, evapotranspiration and sediment deposition. In this study, 2017 land use map is used for the Budhabalanga River Basin. Daily hydro-meteorological information is required for the SWAT model to run the simulation. Factors like wind speed, relative humidity, temperature, solar radiation, and precipitation are used as inputs in weather generator data. Monthly stream flow data of Govindpur NH Bridge site is obtained from the Central Water Commission, Government of India, and is used for simulating and validating the model. The primary works in the model set-up included information arrangement, sub-basin discretization, HRU definition and overlay parameterization, sensitivity investigation and calibration. At last, SWAT model is to simulate the different hydrological segments.

4.4.1 Performance of SWAT- Hydrological model

Land Phase of the Hydrological Cycle

The land phase of hydrological cycle controls the amount of water, sediments, pesticides and nutrient loading in to the main channel of the sub basin. The hydrological cycle as simulated by the SWAT model based in the water balance equation:

$$SWt = SWo + \sum_{i=1}^{t} (Rday - Qsurf - Ea - Wseep - Qgw) \quad \ldots(4.7)$$

Where,

SWt = ultimate soil moisture content (mm)

SWo= initial moisture in soil (mm)

t = time in days

R_{day}= amount of rainfall on day i (mm)

Q_{surf}= surface runoff on day i (mm)

Ea = evapotranspiration on day i (mm)

Wseep = seepage water on day i (mm)

Qgw = return flow on day i (mm)

The model continues daily moisture balance, in each sub basin the evapotranspiration rate differs with different soils and with crops. Thus, the runoff is simulated for individual sub-basin wise and then routed for obtaining overall runoff for basin. The procedure will enhance the efficiency and provides much better physical characterization of moisture balance.

Water or routing phase of hydrological cycle

When SWAT decides loadings of water, sediments, pesticides and supplements into the principal channel, the loadings are routed in the stream system of the basin. SWAT also simulates the changes of chemicals in the stream and streambed. The routing stage incorporates the accompanying two stages

- Routing in the main channel or reach

  It can be further divided into four components –Sediment Routing, Nutrient Routing, Flood Routing, Channel Pesticide routing.
- Routing in the reservoirs.

  It can be further divided into four components- Reservoir outflows, sediment routing, reservoir nutrients and reservoir pesticides.

Assessment of SWAT model's performance

The condition and execution of any hydrological model are normally accessed through the examination of simulated and observed values. The execution appraisal depends on the water balance conclusion of the basin and the understanding of the general state of the time arrangement of release together with the aggregated accumulated volumes. For the most part, the Nash-Sutcliff proficiency (NSE) and the coefficient of determination (R^2) are preferred as statistical performance indices for accessing the model. The scope of R^2 lies within 0 and 1. Ordinarily, $R^2>0.5$ is viewed as adequate.

The various statistical methods are available to evaluate model performance in comparison of simulated values with observed data. The below mentioned various methods are used in this study.

The Coefficient of determination (R^2)

The R^2explains the proportion of the total variance in the observed data that can be explained by the model and it evaluate model goodness, the value ranges from 0 to 1.

$$R^2 = \left[\frac{\Sigma_{i=0}^{n} (y_i^{obs} - y_{mean}^{obs})(y_i^{sim} - y_{mean}^{sim})}{\sqrt{\Sigma_{i=0}^{n} (y_i^{obs} - y_{mean}^{obs})^2 \sqrt{\Sigma_{i=0}^{n} (y_i^{obs} - y_{mean}^{obs})^2}}} \right]^2 \qquad \text{...(4.8)}$$

Nash- Sutcliff Efficiency (NSE)

NSE is a normalized statistic that finds the degree of residual fluctuation compared to measures data variance (Nash and Sutcliffe., 1970). NSE shows how well the plot of observed versus simulated data fits the 1:1 line. NSE is calculated by using the below equation. NSE ranges from 0 to 1, where 1 indicates perfect fit. The NSE has been extensively used to determine the hydrological model preferences (Wilcox et. al., 1990).

$$NSE = 1 - \left[\frac{\sum_{i=0}^{n}(y_i^{obs}-y_i^{sim})^2}{\sum_{i=0}^{n}(y_i^{obs}-y_{obs}^{mean})^2}\right] \qquad ...(4.9)$$

Percentage PBIAS

Percentage bias (PBIAS) measure the mean trend of the simulated data to be larger or smaller than their observed correspondent (Gupta et. al., 1999). The ideal value of PBIAS is zero, with low magnitude value shows rigorous model simulation. Positive values show the model under estimation bias and negative values shows over estimation bias (Gupta et. al., 1999). The PBIAS is derived by using equation below

$$PBIAS = \left[\frac{\sum_{i=0}^{n}(y_i^{obs}-y_i^{sim})}{\sum_{i=0}^{n}(y_i^{obs})}\right] \times 100 \qquad ...(4.10)$$

RSME-Observation Standard Deviation Ration (RSR)

RSME is used to detect the error index data (Chu and Shrimohammadi, 2004; Singh et al., 2004; Vasquez-Amabile and Engel, 2005). The lower value is acceptable and shows better performance of the model. Singh et al.,2004 recommended a model assessment statistic, named RSME- observation Standard Deviation Ratio (RSR). The ideal value is zero, lower the RSR,model will perform well (Moriasi et. al., 2007).

$$RSR = \frac{RMSE}{STDEV_{obs}} = \frac{\sum_{i=0}^{n}(y_i^{obs}-y_i^{sim})^2}{\sum_{i=0}^{n}(y_i^{obs}-y_{obs}^{mean})^2} \qquad ...(4.11)$$

4.4.2 Land use

The land use classification is assessed based on the basis of the land coverage of the study area. The land use is one of the most influential parameters in the surface runoff, evapotranspiration, sediment load transport and ground water recharge etc. SWAT hydrological model analyses the catchment by dividing into small sub basins and further divided into hydrological response units (HRU's) for analysis of soil, land cover management. The land cover statistics are tabulated in Table4.1 with the percentage contribution of the classes taking into consideration of 2011-12 LULC map.

Table 4.1: LULC distribution in the study area

Sl. No.	LULC category	Area in Sq Km	% Area
1	Urban	48.19	1.10
2	Dense Forest	1664.83	38.00
3	Water Body	47.62	1.08
4	Degrade Forest	75.25	1.72
5	Agriculture	2526.76	57.67
6	Barren Land	18.49	0.42

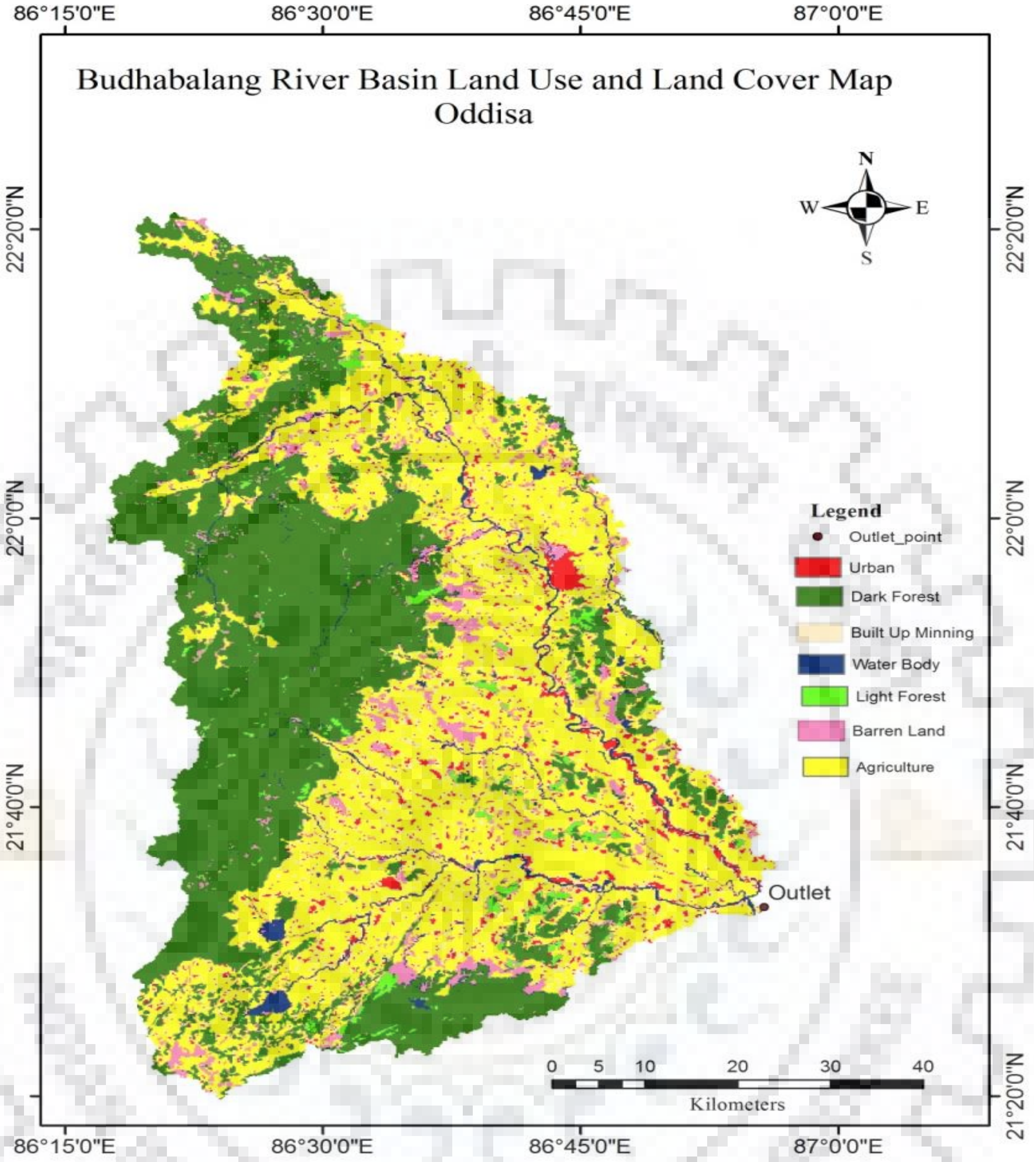

Figure 4.2: Land use map2011-12

4.5 Soil Data

The main classes of soil present in the catchment are represented on the basis of FAO classification as mentioned in table and graphical representation in figure. The soil parameters are almost uniform type soil present in entire catchment i.e. sandy clay loam but differ with the composition and nature and are important in water balance study. The soil classification and composition in the study is presented in Table 4.2.

Table 4.2: Soil classification, composition in the study area

Sl No.	Parameters	Area in Sq. Km	% of Area	Clay %	Silt %	Sand %	Soil type
1	Lf96-2ab-6668	1706.27	38.95	23.00	25.00	51.00	Sandy-clay-loam
2	I-Ne-3729	2211.04	50.47	33.00	25.00	41.00	Loam
3	Nd50-2ab-3819	23.58	0.54	23.00	26.00	50.00	Sandy-clay-loam
4	I-be-3735	425.45	9.71	32.00	22.00	45.00	Loam
5	Ie 692/3a-6663	14.66	0.33	35.00	26.00	39.00	Loam

4.6 Impact of LULC Changes and Climate variability

The impact of LULC changes is to determine the hydrology of Budhabalnga river basin in Northern Odisha over a period of ten years using Remote sensing and GIS techniques. The changes of LULC as ascertained after a gap of ten years exhibits an expansion of urban area inside the catchment. An overall methodological flow chart is given below in Figure 4.3 for achieving the LULC change detection. The land use and land cover generated for the periods 2004 and 2018 are shown in Figures 4.3 and 4.4. Percentage change in Land use in 2004 and 2018 is presented in Table 4.3.

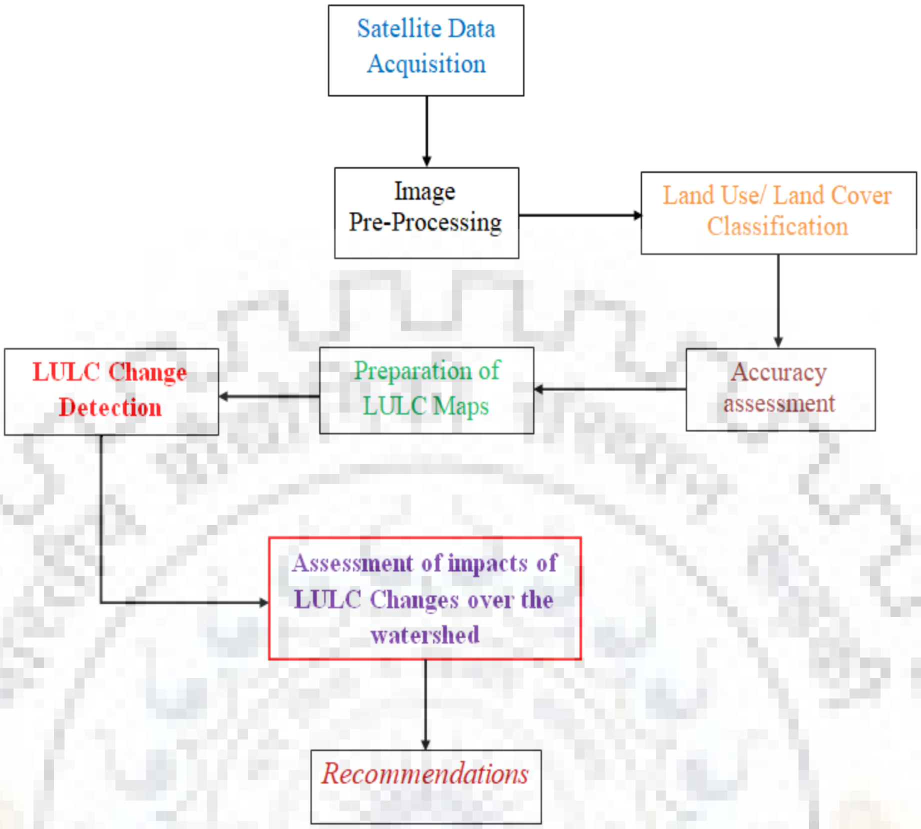

Figure 4.3:Flow chart showing overall methodology of LULC Change detection

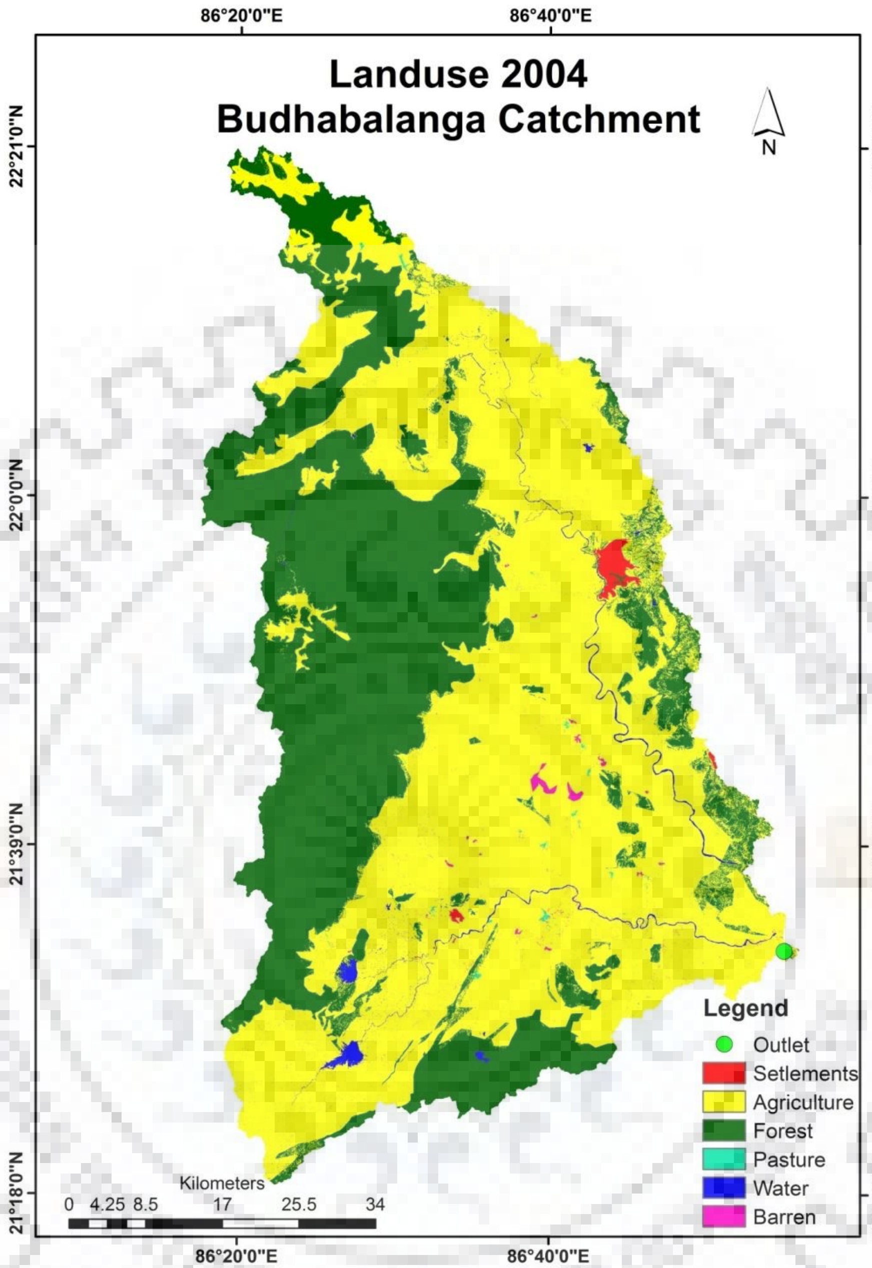

Figure 4.4: Land use 2004 (Budhabalanga Catchment)

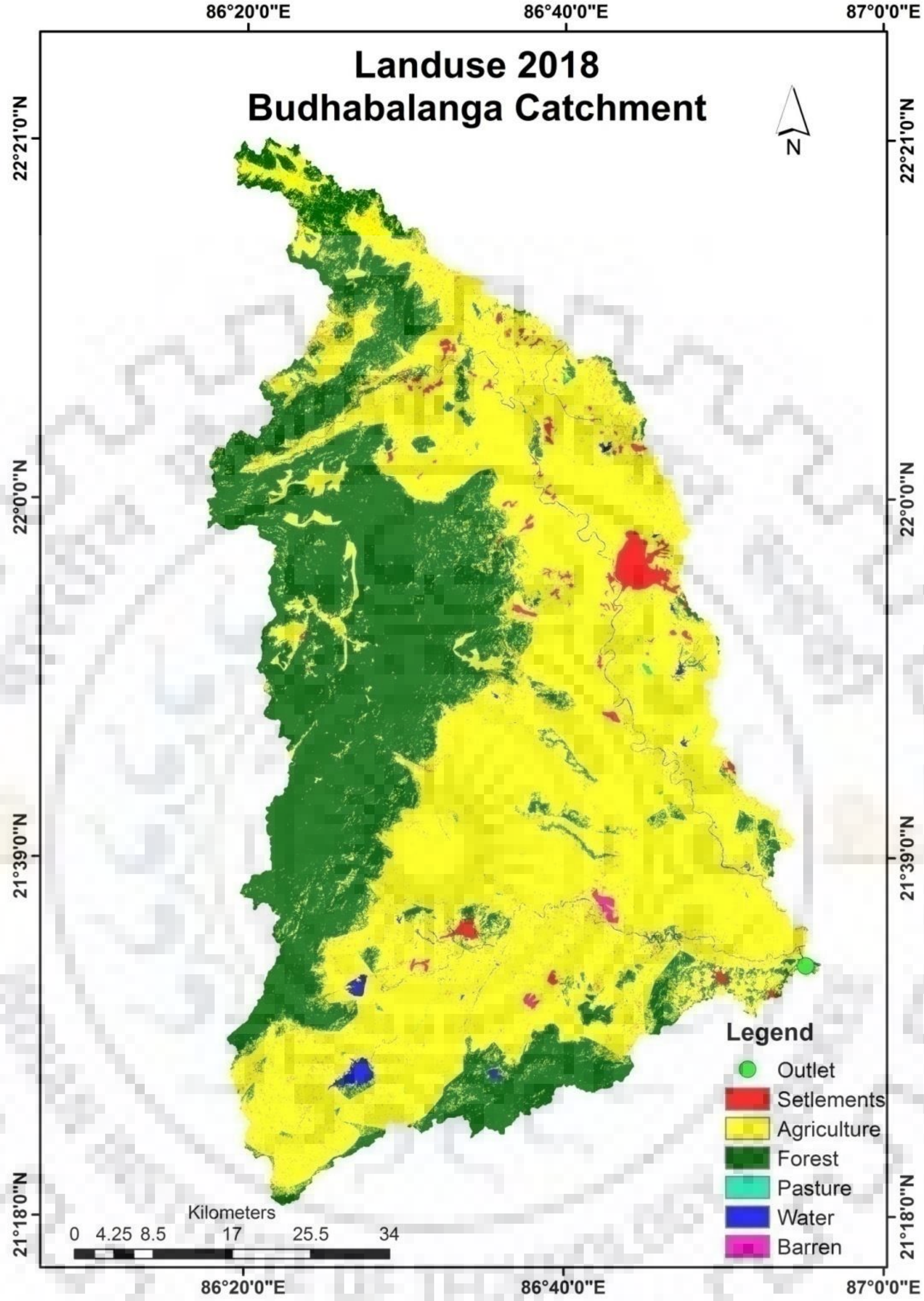

Figure 4.5: Land use 2018 (Budhabalanga Catchment)

Table 4.3: Percentage change in Land use in 2004 and 2018

Category	Year 2004	Year 2018	% change
Urban (Built up)	18.82	62.65	+332.89
Agriculture	2673.78	2764.56	+103.40
Forest	1628.57	1478.88	-9.19
Pasture	11.43	5.69	-50.22
Water bodies	40.24	57.47	+142.81
Barren	10.56	14.16	+134.09

CHAPTER 5: RESULTS AND DISCUSSION

5.1 Trend analysis

The results of Mann-Kendall test at monthly, seasonal and annual basis for stations considered is presented in Table 5.1. It could be noticed that the Z_{mk} values were negative for February except for Kuliana station. Similarly, all the seven stations showed negative trend for June month. The trend was foundto be positive for the November month and December month in all the stations. For all the other months, the trend was increasing at some stations whereas decreasing at other stations. However, very few of them were found to be noteworthy at 10% or 5% significance level. At monthly scale, no station had positive trend at 5% significance level. Only Baripada station during May; Badasahi, Bangriposhi and Betanati during December had positive trends at 10% significant level. Similarly, Remuna in February, Badasahi and Bangriposi in August, and all the stations except Baripada and Betanati in June showed significant negative trend. At seasonal and annual scales, no station possessed significant positive trend. But the stations Badasahi and Remuna showed negative trend during monsoon season. The trend was found to be decreasing for these two stations at annual scale at 5% significance level.

Table 5.1: Z statistics for the seven stations

Stations	Badasahi	Balasore	Bangriposi	Baripada	Betanati	Kuliana	Remuna
Jan	0.486	-0.680	0.555	0.566	0.650	0.177	-1.128
Feb	-0.647	-1.019	-0.187	-0.340	-0.019	0.425	-1.671
Mar	0.428	-0.801	0.000	-0.477	0.354	1.189	-0.692
Apr	-0.286	-0.786	0.375	-0.197	0.322	0.379	-0.877
May	0.250	0.178	1.285	1.802	1.409	0.875	0.054
June	-3.782	-2.480	-1.945	-0.571	-0.428	-1.677	-3.301
July	-1.231	0.089	1.481	1.516	1.124	0.482	-1.338
Aug	-2.533	0.268	-1.624	0.410	0.553	-1.267	-0.874
Sep	-1.588	1.516	1.035	0.731	0.803	0.000	-0.553
Oct	-0.071	-0.107	0.446	0.963	0.856	-0.607	-0.660
Nov	0.486	-0.183	0.348	-0.038	0.038	1.362	-0.419
Dec	1.742	1.040	1.797	1.452	1.772	1.367	1.161
Winter	-0.290	-0.415	0.254	0.728	0.403	1.056	-1.123
Pre-Monsoon	-0.571	-0.161	0.767	0.785	0.946	1.374	-0.250
Monsoon	-2.979	-0.125	-0.446	0.874	1.017	-1.142	-1.802
Post-Monsoon	0.000	-0.071	0.696	0.821	1.070	-0.517	-0.393
Annual	-2.623	-0.303	0.089	1.374	1.588	0.161	-2.141

The outcome of Sen’s Slope test at monthly, seasonal and annual basis for the seven stations considered was presented in Table 5.2. It could be seen that the results of Sen’s Slope Estimator test was quite similar to that of Mann-Kendall test. The trend was insignificant for the months of January to March, November, December at all the stations. The trend was found to be negative for the months of Southwest Monsoon season. The trend was remarkably negative for both the stations i.e. Badasahi and Remuna, during Monsoon season as well at annual scale. As the rainfall trends for the monsoon season was negative, it was quite obvious for the annual rainfall to follow a decreasing trend.

Table 5.2: Sen’s slope estimator for the seven stations

Stations	Badasahi	Balasore	Bangriposi	Baripada	Betanati	Kuliana	Remuna
Jan	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0
Apr	-0.077	-0.611	0.333	-0.067	0.115	0	-0.5
May	0.333	0.250	1.933	3.425	2.111	1.478	0.133
June	-7.571	-7.143	-4.893	-2.25	-0.765	-3.941	-7.889
July	-2.5	0.6	4.6	4.904	2.429	1.613	-4.556
Aug	-5.182	0.407	-3.8	1.021	1.6	-3.22	-3.529
Sep	-4.3	3.6	2.575	2.643	1.692	0	-1.333
Oct	-0.083	-0.267	1.111	3.05	1.875	-0.767	-1.111
Nov	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0
Winter	0	0	0	0	0	0.222	-1.0
Pre-Monsoon	-1.1	-0.563	1.392	1.24	1.357	2.75	-0.286
Monsoon	-18.062	-0.85	-1.3	6.188	5.917	-3.181	-15.667
Post-Monsoon	0	-0.125	1.822	2.5	2.727	-1	-0.909
Annual	-20.647	-3.763	0.5	13.423	12.206	1	-20.25

Table 5.3: Results of the Trend analysis of Rainfall Budhabalanga catchment (1988-2018)

Time series	Z statistics	Significance.	Sen's slope (Q)
Jan	-0.159298		0
Feb	-1.561709		-0.3
Mar	-0.86803		-0.2
Apr	0.492967		0.45
May	1.172922		1.64
Jun	-2.498834	*	-5.1
Jul	0.696954		1.22
Aug	-0.798947		-1.8
Sept	-0.15299		-0.4
Oct	-0.526965		-1.2
Nov	-0.361818		0
Dec	0.838381		0
Annual	-1.036931		-5.3
Pre-monsoon	1.002933		1.49
Monsoon	-1.342911		-5.4
Post-monsoon	-0.322979		-1.1
Winter	-0.579274		-0.2

The following observations were made from the Z statistics of the Trend analysis of Rainfall Budhabalanga catchment (1988-2018) in Table 5.3 above.

- Annual rainfall is showing non-significant decreasing trend.
- Annual Sens slope (Q) shows 5.3 mm decrease in rainfall magnitude.
- June month rainfall shows 95 % decreasing trend with 95 % of significance.
- The average annual rainfall in the basin is 1524 mm

5.1.1 Trend analysis of temperature by MK test and Q test

The result of Mann Kendall statistics Z_{mk} and Sen's Slove for mean of Maximum temperature for all the twelve months from 1988 to 2018 is represented in Table 5.4 and figure 5.1 below. From the values on the test Feb to May and Aug to November months the maximum temperature is showing increasing trend and other four months like Jan, June, July and December showing decreasing trend.

Table 5.4 Trend analysis of Long Term maximum temperature

Test Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mann Kendall Zmk	-0.53	0.63	1.57	1.48	0.09	-0.50	-0.25	1.65	1.84	0.39	0.32	-0.24
Level of significance						+			+			
Sen's Slope	-0.018	0.016	0.022	0.023	0.002	-0.015	-0.004	0.011	0.014	0.015	0.006	-0.003

It is observed from the table 5.5 and figure 5.2 that the trend for mean of minimum temperature for the months January to May and July to October showing increasing trend where as in the months June, November and December exhibiting falling trend. The positive trend values 1.95, 1.71 are at 0.05 significant level. The positive Sen's slope indicates the rising trend in the Budhabalanga basin. the Highest Sen's Slope is 0.024^{0}C for the month of February and the lowest slope is -0.006^{0}C in the month of December.

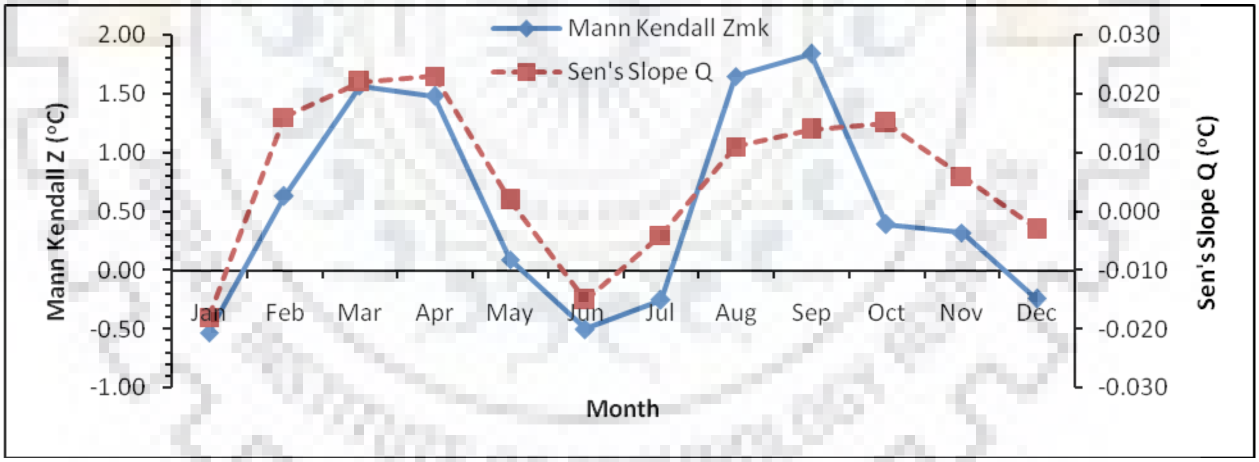

Figure 5.1: Maximum temperature trend analysis (Period 1988-2018)

Table 5.5 Trend analysis of Long Term minimum temperature

Test Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mann Kendall Zmk	0.50	1.95	1.71	0.58	0.58	-0.13	0.94	1.71	0.22	0.63	-0.14	-0.48
Level of significance		+	+					+				
Sen's Slope	0.005	0.024	0.015	0.005	0.009	-0.002	0.006	0.011	0.002	0.005	-0.003	-0.006

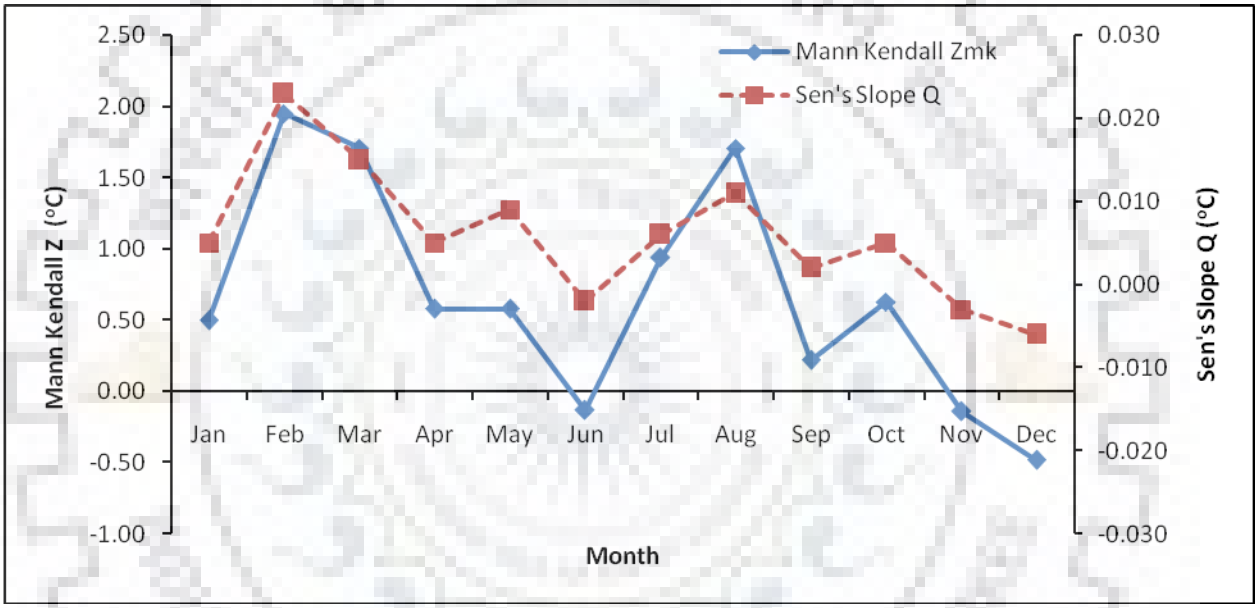

Figure 5.2: Minimum temperature trend analysis (Period 1988-2018)

5.2 Land Phase of Hydrological cycle of Budhabalanga River Basin

The hydrological water balance of Budhabalanga River Basin shows circulation of hydrological constituents and their respective values simulated by SWAT model. The hydrological model helps in understanding and estimating of future circulation of water resources in time period and volume. Figure 5.3 shows the surface runoff is 33% of total surface precipitation and about 39.65% of losses through the evapotranspiration in the catchment with respect to rainfall received in catchment after simulation on annual basis. The average annual water balance parameters after simulation in SWAT is displayed in Figure 5.3 below. The sediment yield from the basin is represented in Figure 5.4.

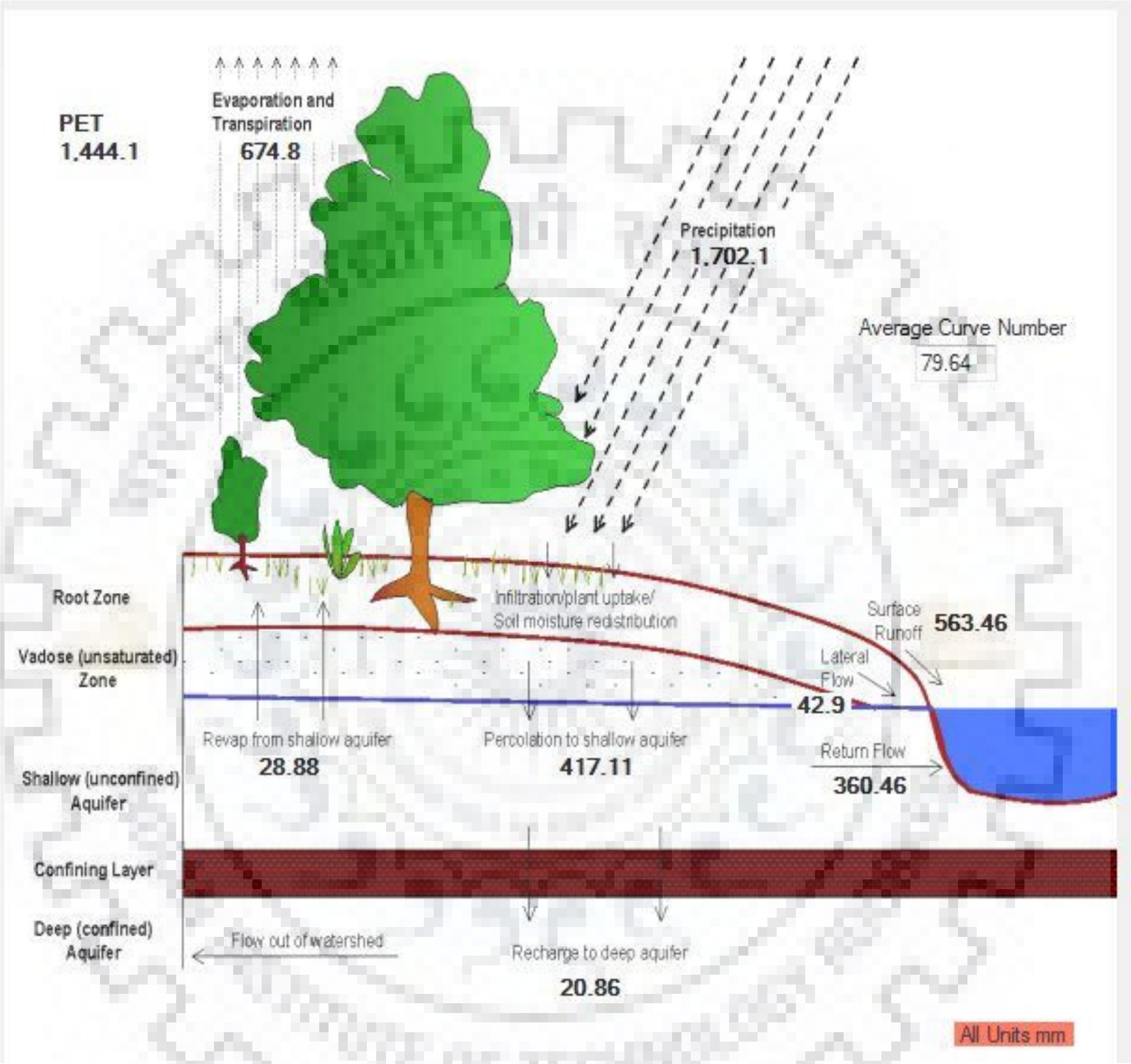

Figure 5.3: Hydrological cycle of Budhabalanga River Basin

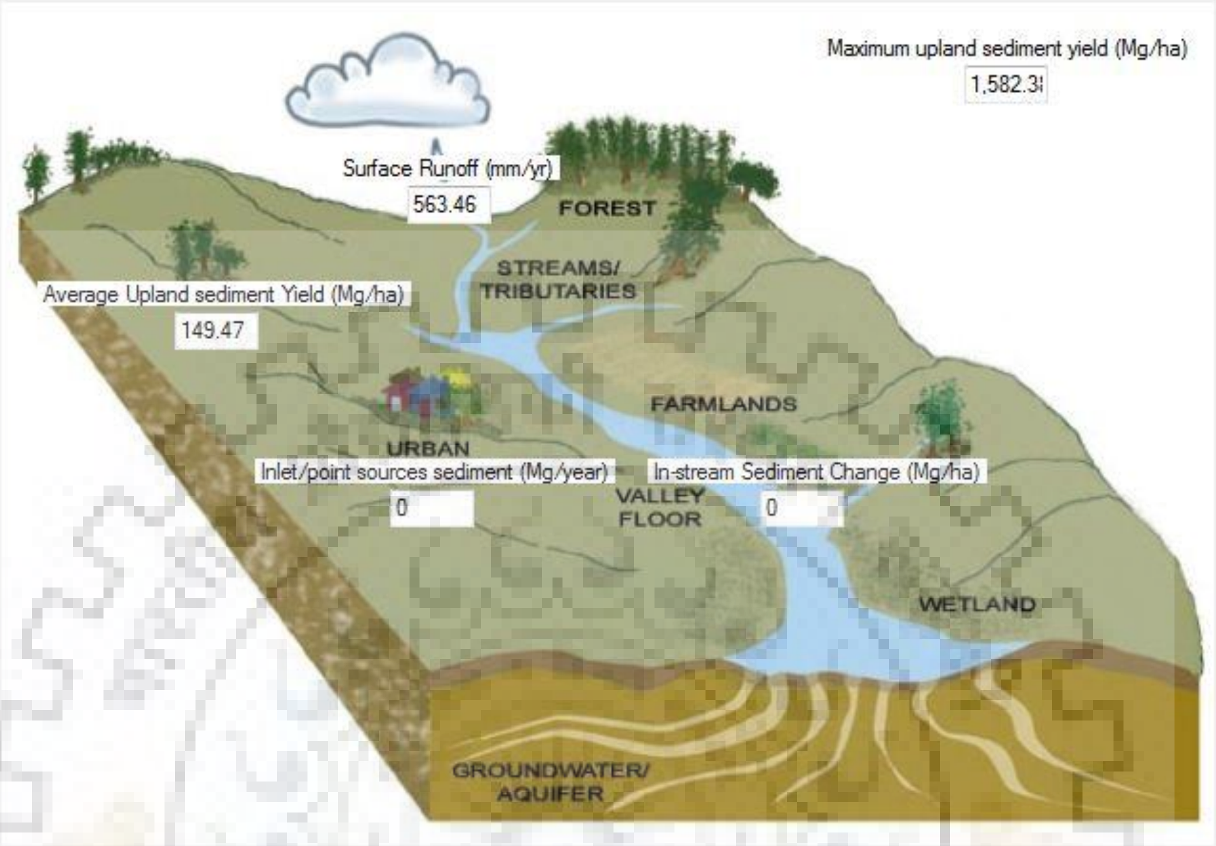

Figure 5.4: Sediment yield in the basin

5.3. Simulated, Calibrated and Validated results on daily basis

5.3.1. Discharge taken on daily basis

Simulation and calibrated of the model was carried out for the time period of 2003 to 2010 .The warm up period is considered for the first three years. After calibration the model was also validated for the period of four years i.e. from 2011 to 2014.

Pre Simulated Period

The results of simulation observed to be that the model to be higher peak flows than the measured field data. The NSE (Nash-Sutcliffe efficiency), is 0.186 and correlation coefficient,

$R^2$is 0.582 for the initial simulated data as shown in Figure 5.5 and 5.6 for improving calibration results the parameters are to be adjusted for obtaining better efficient correlation.

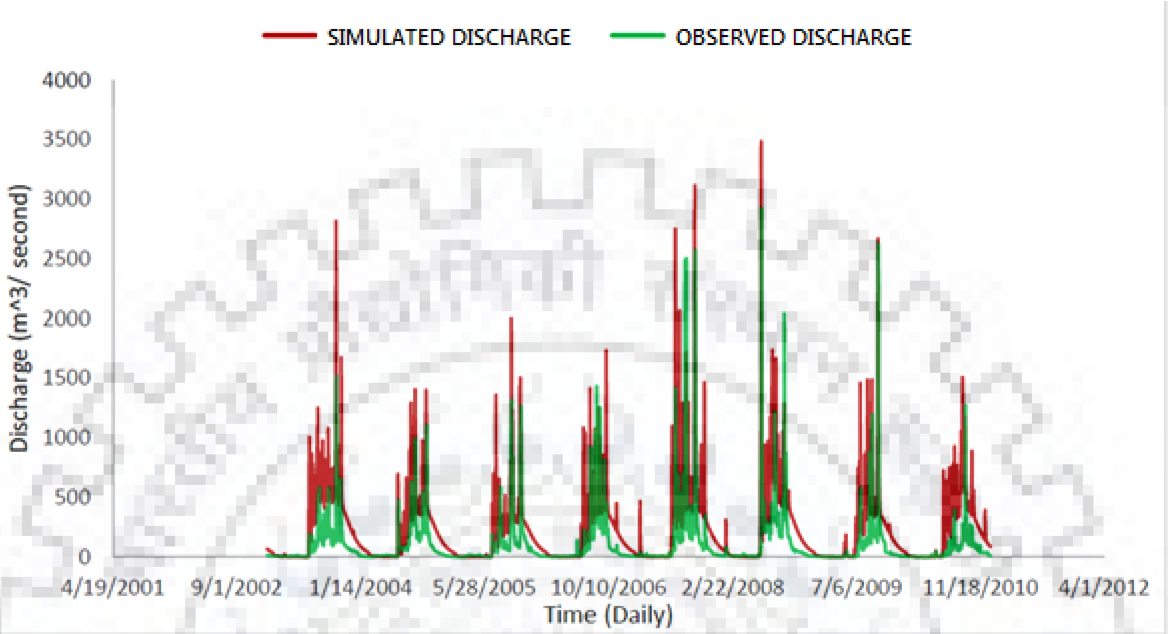

Figure 5.5: Discharge simulated vs Discharge observed on daily data

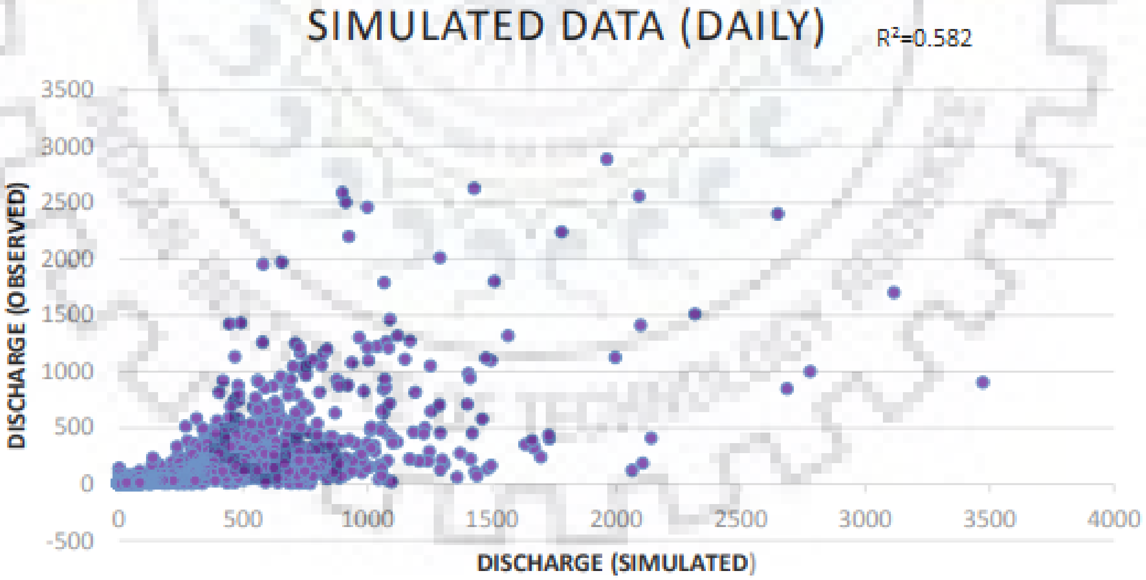

Figure 5.6: Simulated discharge vs observed discharge

Calibrated Period

It is observed from Figures 5.3 and 5.4 that the simulated discharge is lower than the measured flow data, hence, in order to make comparable the simulated discharge with respect to observed discharge calibration of the values is necessary. By changing certain input parameters of the model the high flows predicted by the model is reduced improving the simulated flow results. Hence the threshold depth of water was decreased and available water capacity and soil evaporation compensation factor were increased as suggested in the SWAT CUP user manual. The NSE (Nash-Sutcliffe efficiency) is 0.63 and the correlation coefficient R^2 is 0.648 for the calibrated data as depicted in Figure 5.7 and 5.8 The performance evaluation of the model is appropriate.

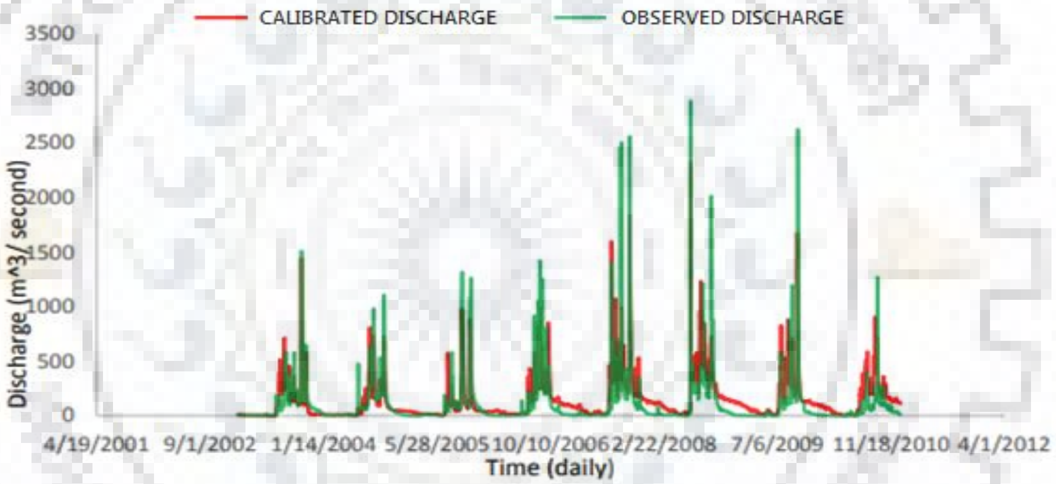

Figure5.7: Discharge calibrated vs observed on daily basis

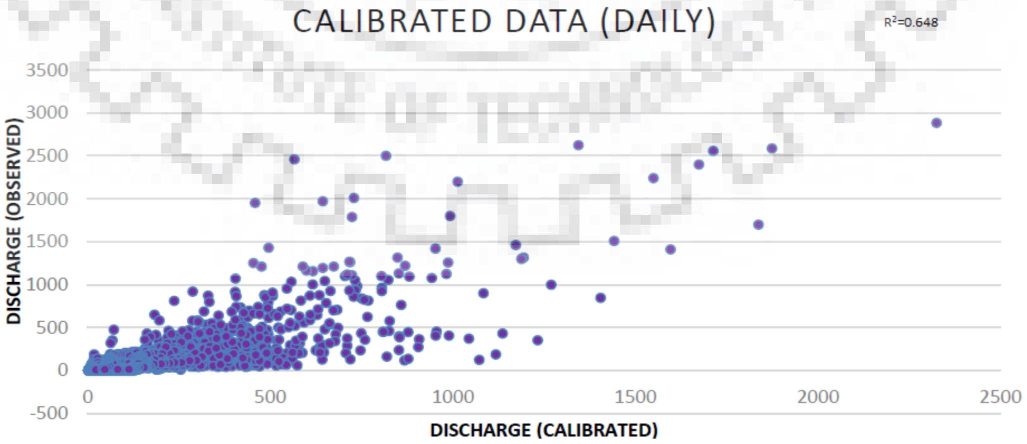

Figure 5.8 Observed data vs Calibrated data

Validation Period

Model is validated for the period 2011 to 2014. The NSE (Nash-Sutcliffe efficiency), is 0.58 and the correlation coefficient R^2 is 0.637 for the validated period for surface flow as shown in Figure 5.9 and 5.10. Due to irregular precipitation the model was not able to exhibit the peak flow in the year 2011.

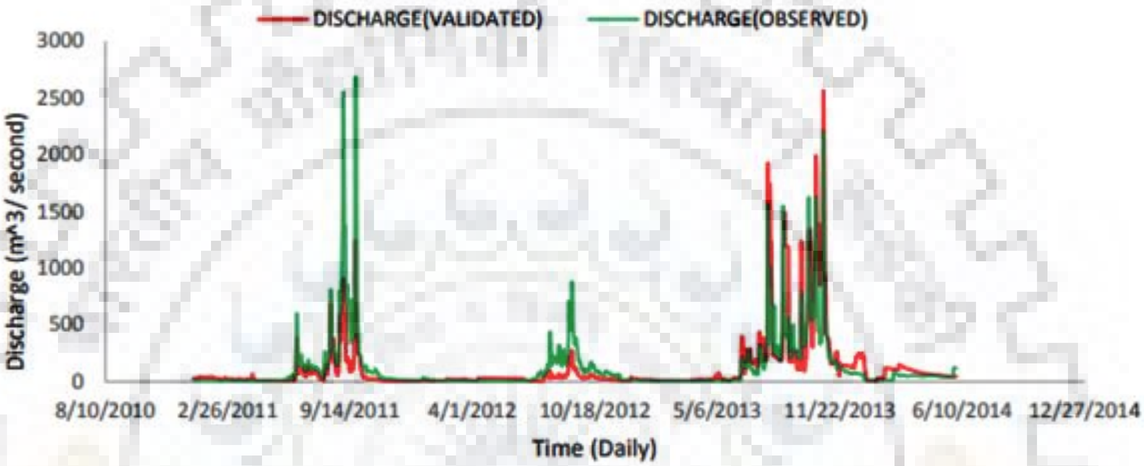

Figure 5.9: Discharge Validated Vs Observed data on daily basis

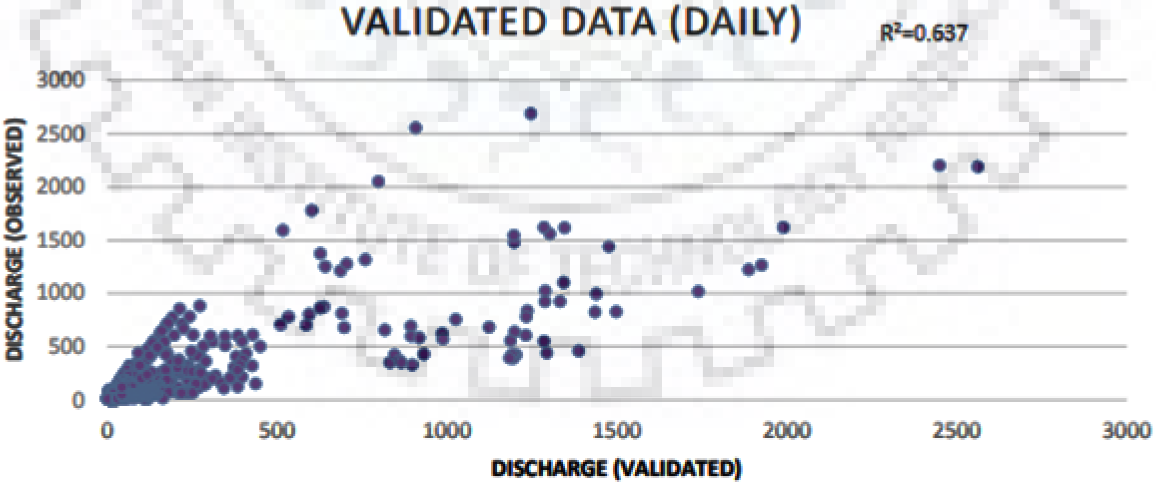

Figure 5.10: Validated data vs Observed data

In tabular form below (in Table 5.6) all the results of the parameters, goodness of fit, of the simulated, calibrated and validated data have been represented below.

Table 5.6 Model performance evaluation statistics of SWAT in daily time step

Data Sets	**R^2**	**NASH - SUTCLIFFE EFFICIENCY**	**PBIAS**	**Performance rating**
PRE SIMULATED PERIOD (2003-2010)	0.582	0.186	39.9	-
CALIBRATED PERIOD (2003-2010)	0.65	0.63	-9.0	Satisfactory
VALIDATED PERIOD (2011-2014)	0.64	0.58	13.2	Satisfactory

5.3.2 Monthly Time Step

In this monthly time period calibration was done and the results were measured with the daily time period graphs which has been shown below.

Simulated Period.

It is a comparative representation of flow hydrograph between discharge simulated vs discharge observed in monthly time scale. The Nash-Sutcliffe efficiency, NSE and coefficient of correlation R^2 is found to be 0.184 and 0.683 respectively which is exhibited in the Figure 5.11 and Figure 5.12.

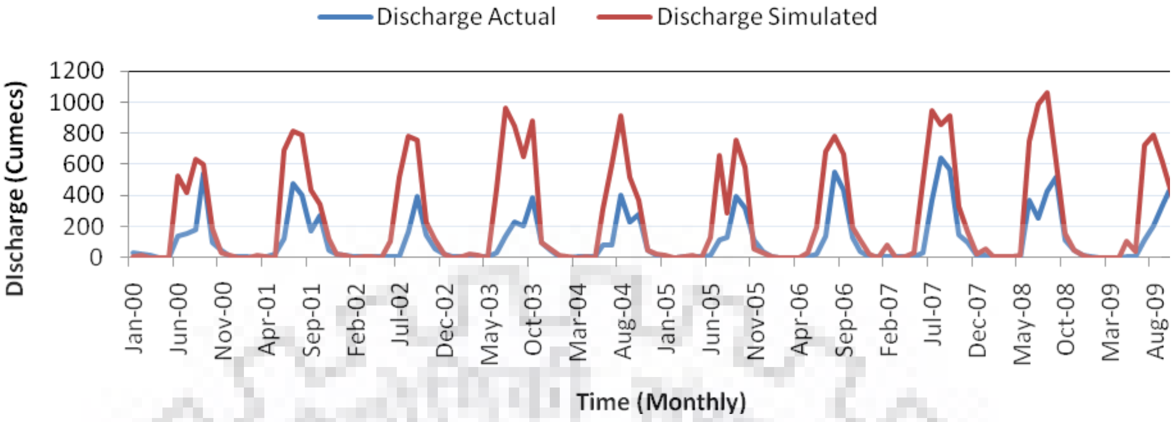

Figure 5.11: Calibration phase of simulated and observed stream flow at Budhabalanga RiverBasin

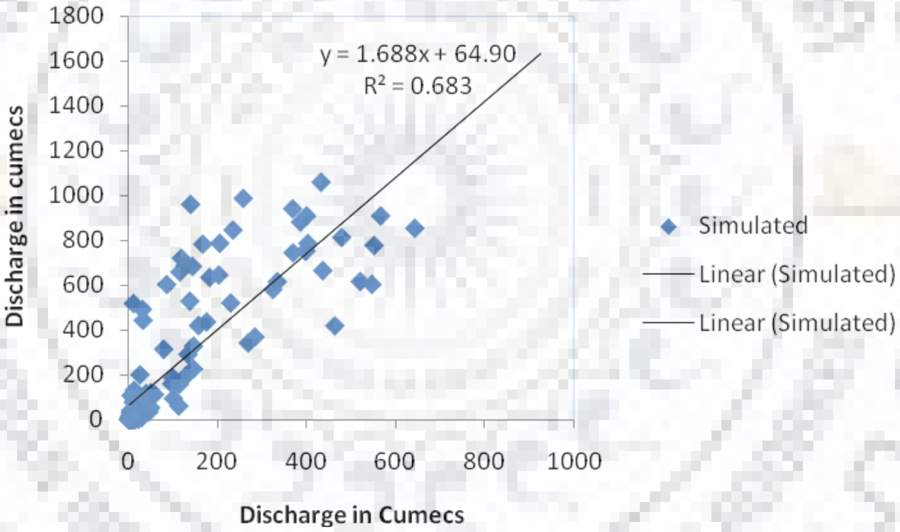

Figure 5.12: Simulated vs. Observed discharge (2000-2014)

Calibrated Period

In this graph calibration period as shown in figure 5.13 and figure 5.14 Nash-Sutcliffe efficiency (NSE) and co-efficient of determination (R^2) are found to be 0.62 and 0.68respectively. As per the performance evaluation criteria these values are considered to be good.

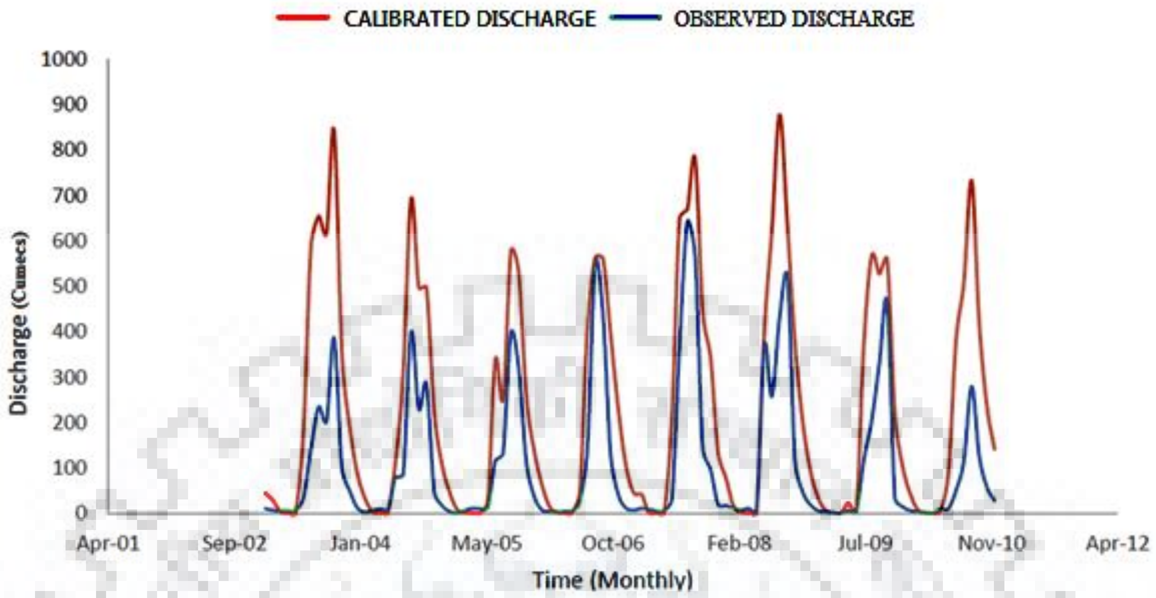

Figure5.13: Calibrated vs. Observed discharge on monthly basis

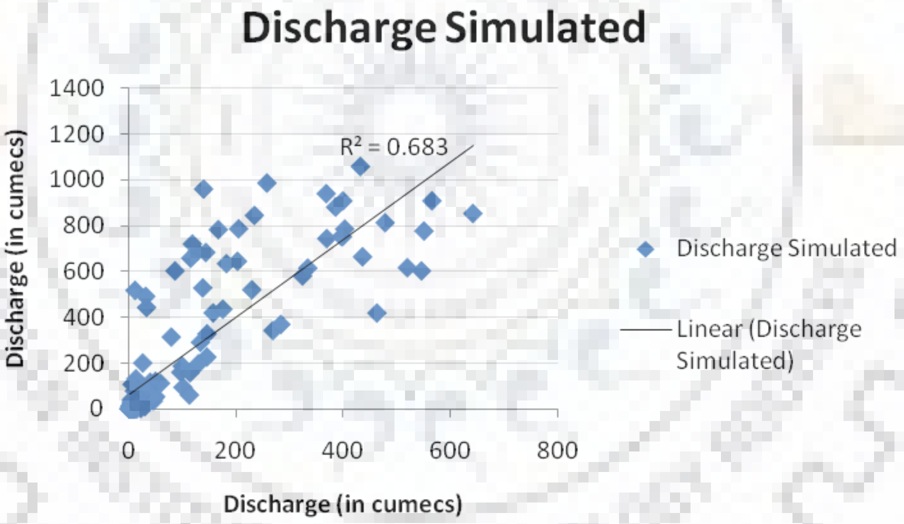

Figure 5.14: Discharge Calibrated Vs Observed

Validation period

Calibration of the model is again validated for the period 2010 to 2014 and the results of the NSE and R^2 for the validated of surface runoff are 0.76 and 0.81 respectively as exhibited in Figures 5.15 and 5.16 below. Model performance and efficiency is good.

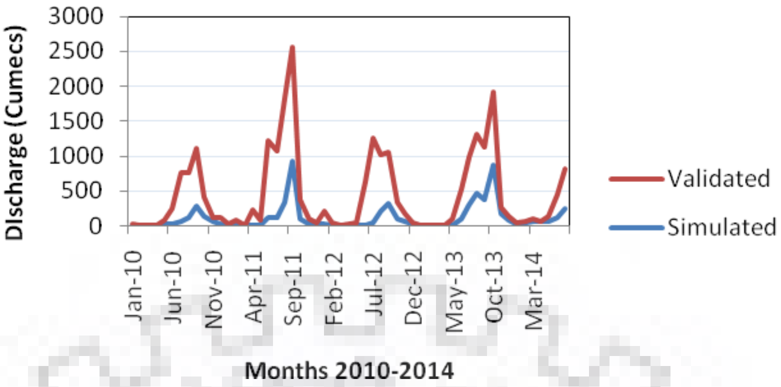

Figure 5.15: Validated vs. Observed discharge data on monthly basis

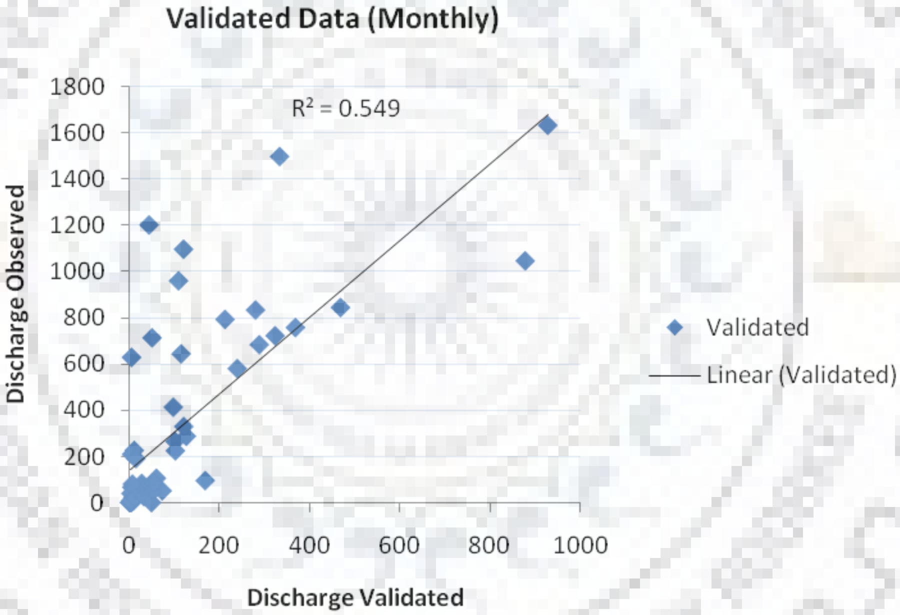

Figure 5.16: Scatter plot between observed and simulated flow at Budhabalanga River Basin

Table No 5.7 below shows the model performance of goodness of fit for Simulated, Calibrated and Validated results. It is ascertained from the statistical parameters that the model performance was good for calibration and validation.

Table 5.7: Performance evaluation for monthly time period

Data Sets	R^2	NASH - SUTCLIFFE EFFICIENCY	PBIAS	Performance Rating
SIMULATED PERIOD (2003-2010)	0.683	0.184	32.5	-
CALIBRATED PERIOD (2003-2010)	0.683	0.62	7.0	Good
VALIDATED PERIOD (2011-2014)	0.81	0.76	12.9	Very Good

The study area is getting changed due to the change in LU which is reflected in runoff application including other weather parameters. However, the runoff estimation is done through this model is represented in five typical years as stated in the table 5.8 below

Table 5.8 Observed vs simulated discharge

Year	Average daily observed discharge (m^3/sec)	Average daily simulated discharge (m^3/sec)
2001	133.57	255.31
2006	114.75	214.26
2007	160.55	304.13
2008	151.07	299.99
2013	198.79	325.08

5.3.3. Sensitivity and uncertainty analysis

sensitivity analysis is one of the important stage of model calibration, validation and construction for acceptance. It is manifest how input in model will have an impact on steam flow during calibration (Kannan et al., 2007). The essential parameter considered for the SWAT in study are tabulated in Table 5.9. The result for simulation in SWAT CUP expressed as 95 percent prediction uncertainties (95 PPU), usually not used for comparison with observed data using R^2. NSE and RSR values. Each parameter is to be set in a range and do set of simulations. The same procedure was continued for all considered parameters, finally best fitted values were obtained. By using these values maximum and minimum range for these fitted values are again simulated to get the best simulated plot. The rank for each parameter is assigned based on the values of P-factor and shown in table 5.9. Extensively the p-factor and r-factor are used to endorse the power of unpredictability estimation and model calibration (Schuol et al., 2006)

For further calibration of flow parameters the P-Value and t-Stat value has been displayed in figure 5.17 to have better calibration efficiency.

Table 5.9 SWAT Parameters with ranges and best fitted values for the case study

S.N.	Parameter Name	Fitted Value	Min value	Max value	t-Stat	P-Value	Physical description	Rank
1	R__CN2.mgt	-0.029	-0.116	0.028	30.889	0.000	SCS runoff curve number for moisture condition II.	1
2	V__CH_N1.sub	0.151	0.010	7.631	-11.127	0.000	Manning's "n" value for the tributary channels.	2
3	V__ALPHA_BF.gw	0.986	0.684	1.000	9.612	0.000	Baseflow alpha factor, Days.	3
4	V__RCHRG_DP.gw	0.394	0.276	0.829	-4.063	0.000	Deep aquifer percolation fraction.	4
5	V__OV_N.hru	0.254	0.010	0.318	-3.883	0.000	Manning's "n" value for overland flow.	5
6	V__GW_DELAY.gw	354.441	118.384	355.270	3.412	0.001	Groundwater delay, Days.	6
7	V__CANMX.hru	24.329	0.000	31.698	-3.070	0.002	Maximum canopy storage.	7
8	R__SOL_K(..).sol	0.131	0.063	0.293	-2.410	0.016	Saturated hydraulic conductivity.	8
9	R__SOL_BD(..).sol	-0.017	-0.153	0.015	-1.885	0.060	Moist bulk density.	9
10	V__GWQMN.gw	2646.763	1676.641	4017.105	-1.315	0.189	Treshold depth of water in the shallow aquifer required for return flow to occur, mm.	10
11	V__CH_N2.rte	0.035	0.024	0.208	-1.258	0.209	Manning's "n" value for the main channel.	11
12	V__ESCO.hru	0.015	0.000	0.300	1.110	0.267	Soil evaporation compensation factor.	12
13	R__SOL_AWC(..).sol	0.035	-0.240	0.047	-0.959	0.338	Available water capacity of the soil layer.	13
14	V__EPCO.hru	0.878	0.539	0.879	0.744	0.457	Plant uptake compensation factor.	14
15	V__SLSUBBSN.hru	67.779	64.822	102.981	0.564	0.573	Average slope length.	15
16	R__HRU_SLP.hru	-0.094	-0.101	0.035	0.511	0.609	Average slope steepness.	16
17	V__REVAPMN.gw	481.591	274.120	500.000	0.386	0.699	Threshold depth of water in the shallow aquifer for "revap" to occur, mm.	17
18	V__GW_REVAP.gw	0.066	0.038	0.103	-0.381	0.703	Groundwater "revap" coefficient.	18
19	V__SURLAG.bsn	16.438	12.954	21.697	0.197	0.844	Surface runoff lag time.	19
20	V__CH_K2.rte	405.003	317.353	512.782	0.173	0.862	Effective hydraulic conductivity in main channel alluvium.	20
21	R__SOL_Z(..).sol	-0.156	-0.185	0.066	-0.062	0.951	Depth from soil surface to bottom of layer.	21

Note: v_ means parameter value is to be replaced by given value within the range and r_ means the parameter value is multiplied by (1+ the give value

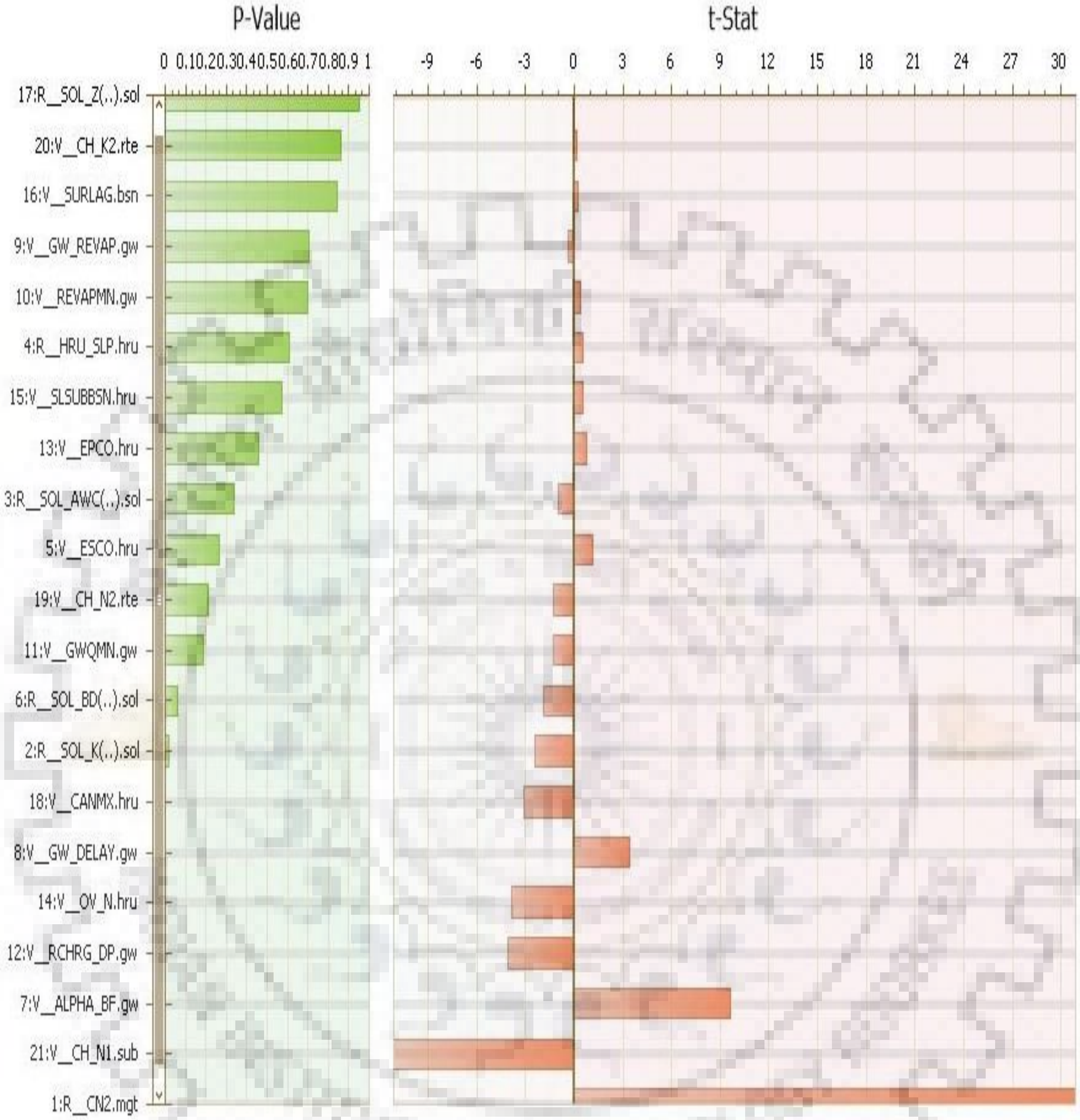

Figure 5.17 Sensitivity analysis of Flow Calibration Parameters

A precipitation analysis has been done from the year 2000 to 2018 to ascertain the pattern of rainfall in the basin as exhibited in the figure 5.18 below.

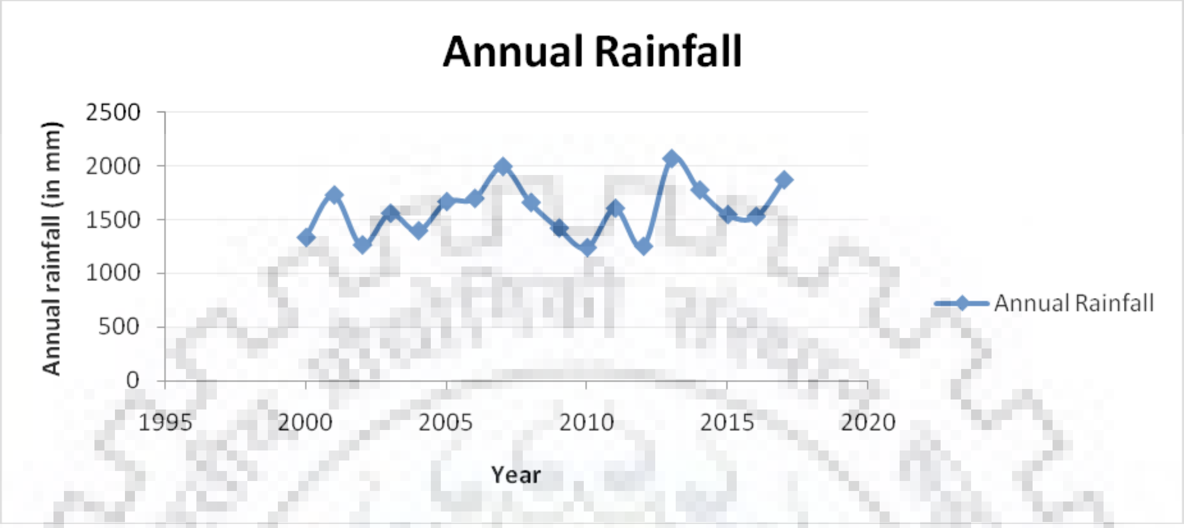

Figure 5.18: Plot of Annual precipitation vs year

It is observed that the trend of rainfall is varying for the past 18 years, the number of days which exceeded 35 mm of rainfall (high intensity rainfall) for the past 8 years with a gap of 2 years was calculated as shown in the figure 5.19.

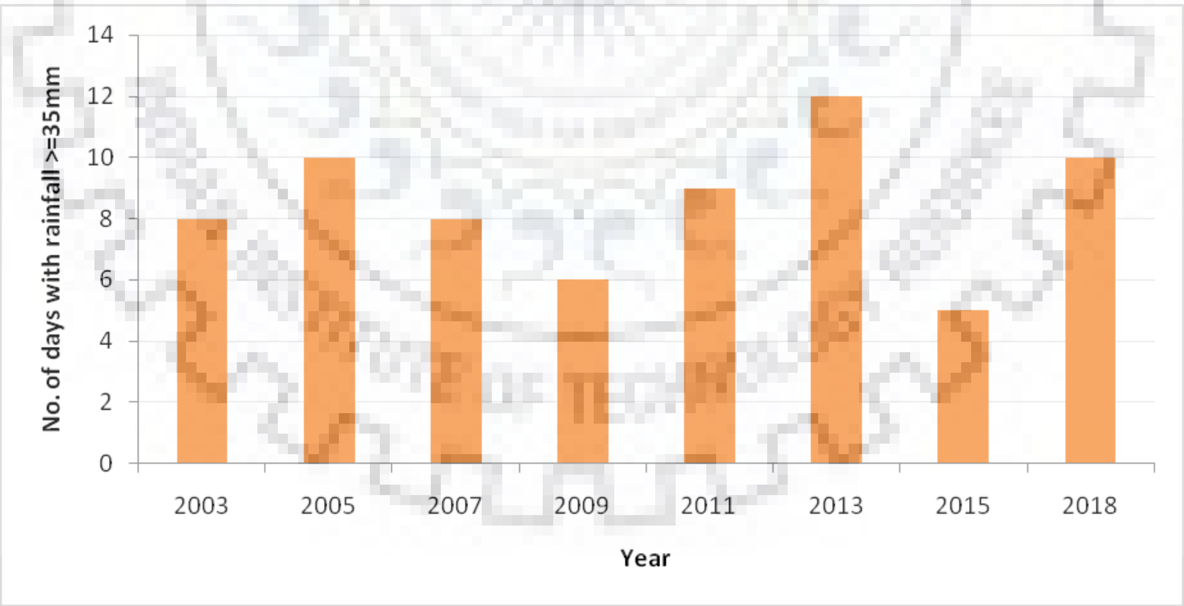

Figure 5.19: Plot of number of days with rainfall >=35mm vs year

The graph clearly depicts the rainfall of high intensity is in a rising trend 2009 to 2018. As a result of which the runoff is increased in the basin gradually due to increase in precipitation, which is due to the change in land use pattern.

CHAPTER 6: CONCLUSIONS AND FUTURE SCOPE

6.1 General

For agricultural planning and water resources development, it is necessary to consider the spatial distribution of weather parameters like rainfall, maximum temperature, minimum temperature and evapotranspiration under climate change conditions. Any change in precipitation will severely affect the stream flow in a basin which is further controlled by the ecosystem and landscape changes. Evapotranspiration is also impacted by vegetation, soil cover, sun radiation, temperature and wind, which ultimately decides the water availability. In an era when urbanization is rampant coupled with rising population, the climate change impact assessment at basin level is necessary to correctly assess the water availability, crop water requirement, and overall water management.

The study is taken for Budhabalanga river which is a sub basin of Subarnarekha river basin. In this study trends of weather parameters viz. rainfall, maximum temperature, and minimum temperature are investigated to assess the variability at temporal and spatial scale. Further, land use and land cover change detection has been made for the periods 2004 and 2018. The existing land use is considered to assess the stream flow of the basin using SWAT model. SWAT model is employed which runs under ArcGIS interface. It is used to find out the runoff the basin through Hydrological modelling of the study area. Model simulation, calibration and validation is done from 2001 to 2014.

6.2 Conclusion

The followings are the key observations/ findings of the study:

- The average rainfall of the basin during the periods 1988 to 2017 (30 years) is in upward (increasing) trend although not significant. In pre-monsoon season the rainfall trend is increasing but in winters, monsoon and post-monsoon the trend is decreasing and non-significant However, this has an adverse effect on cropping season, cropping period and ultimately on crop production.

- The Mann Kendall statistics Z_{mk} and Sen's Slope for mean of Maximum temperature for all the twelve months from 1988 to 2018 gives the result that the February to May and August to November months the maximum temperature is having increasing trend and other four months like January, June, July and December decreasing trend.
- It is observed that the trend for mean of minimum temperature for the months January to May and July to October showing increasing trend where as in the months June, November and December exhibiting falling trend. The positive trend values 1.95, 1.71are at 0.05 significant level. The positive Sen's slope indicates the rising trend in the Budhabalanga basin. The highest Sen's Slope is 0.024^0C for the month of February and the lowest slope is -0.006^0C in the month of December.
- 2 sub-basins and 16 HRUs are found to exist in the catchment during run of the SWAT model.
- By studying the land use of 2004 and 2018, it is observed that the urban (Built up) area and the agriculture area has been increased during last 14 years. Urban area has been increased considerably in the areas such as Baripada, Betanati, Khunta, Udala, Bangiriposhi and Kapipada. The forest land has been decreased marginally. Though the changes observed are not very significant in case of forest and agriculture land but the urban land has increased to more than three times that of year 2004. Hence, such a change in land use has a greater impact on the future hydrology of the basin.
- The increase in runoff in the study area is predominantly due to the impact of land use and land cover changes thereby changing the hydrology of the basin. In addition to this other climatological variables also affect the quantity of surface flow although insignificantly.
- In daily time period, the results of measured and calibrated values of NSE and R^2 were 0.63 and 0.65 respectively during calibration period where as in case of measured and validated the values of NSE and R^2 were 0.58 and 0.64 respectively during model validation.
- Likewise the comparative values for monthly time step of measured and calibrated period in respect of NSE and R^2 observed to be 0.72 and 0.77. But in case of the results of measured and validated were 0.76 and 0.81 for the values of NSE and R^2 respectively.

6.3 Future scope of work

For evaluation of water availability in a projected time series for sustainable requirement could be a further advancement of this work. Development of best management practices (BMPs), adaption mitigation policies are required to better handle the effects of change in LULC and climate variability. Water evaluation and assessment planning is necessary to solve the versatile problems for better planning and management of water resources, which will help to avoid extreme events.

Followings are the few works which is proposed under future scope:

1. Finding water use efficiencies (water productivity) at all scales, from field level water application to water allotments in the channel order regions, and its enhancement through utilization of reused water for water system, restoration of the water bodies, for example, tanks and lakes to expand the capacity of the basin.
2. The mapping of water stress area in the catchment can be determined by applying temporal land use change due to the effect of spatial, temporal, inter annual variability in rainfall, intensity of precipitation pattern and intelligent water management practices
3. Assessment of the future irrigation demands in the catchment with the help of hydrological model (SWAT) for future planning.

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